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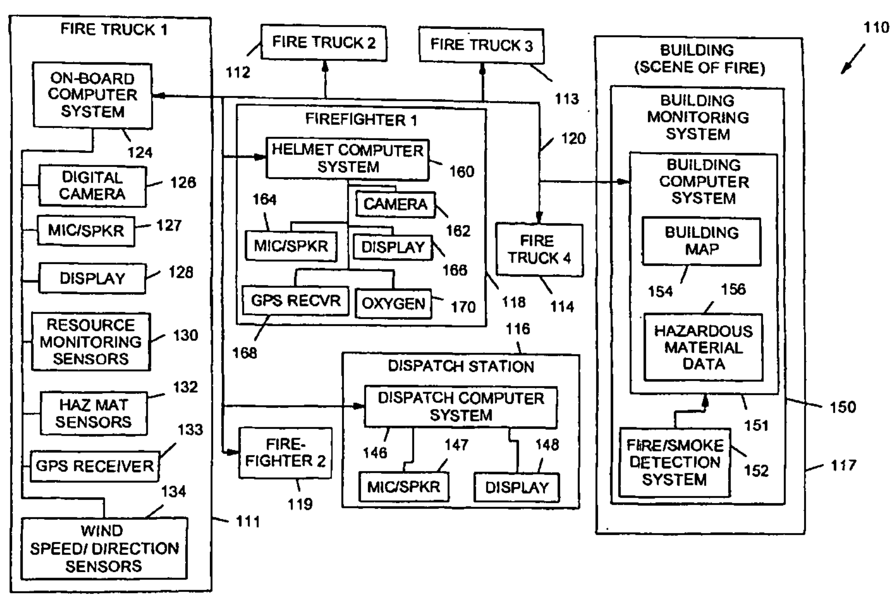
(54) Title: FIRE FIGHTING VEHICLE AND METHOD WITH NETWORK-ASSISTED SCENE MANAGEMENT



(57) Abstract: A method comprises acquiring information pertaining to a scene of a fire. The acquiring step is performed by a sensor connected to a first computer. The method further comprises transmitting the information from the first computer to a second computer by way of a wireless communication network. The second computer is mounted to a fire fighting vehicle and is connected to a display. The method further comprises displaying the information at the fire fighting vehicle using the display.

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FIRE FIGHTING VEHICLE AND METHOD WITH NETWORK-ASSISTED SCENE MANAGEMENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Prov. No. 60/342,292, filed December 21, 2001, entitled "Vehicle Control and Monitoring System and Method," U.S. Prov. No. 60/360,479, filed February 28, 2002, entitled "Turret Control System and Method for a Fire Fighting Vehicle," and U.S. Prov. No. 60/388,451, filed June 13, 2002, entitled "Control System and Method for an Equipment Service Vehicle."

BACKGROUND OF THE INVENTION

[0002] The present invention relates to fire fighting vehicles, systems and methods. In a preferred embodiment, this invention relates to fire fighting vehicles, systems and methods that communicate information over a network to assist with scene management.

[0003] At the scene of a fire, there is often a significant amount of ongoing activity. In order to make effective decisions regarding resource allocation, equipment and personnel placement, fire fighting tactics, and so on, it is desirable that fire fighters and related personnel have access to as much information as possible regarding the scene of a fire. In practice, however, access to such information at the scene of a fire is often limited by practical difficulties associated with acquiring and communicating such information. For example, when several fire fighting vehicles are at the scene of a fire, it is often difficult to obtain a quick and accurate assessment regarding the status of each vehicle. For example, fire fighting vehicles carry certain resources which are capable of being depleted, such as fuel, battery, water, foam and oxygen supplies. Often no easy way for a fire fighter or other individual to assess the status of each vehicle to determine which vehicles need to be resupplied, particularly if it is desired to obtain such information for all fire fighting vehicles present at the scene of a fire. On the other hand, it is undesirable to resupply a fire fighting vehicle too soon because that results in the vehicle is unnecessarily taken out of action, thereby limiting its fire fighting effectiveness. Likewise, other situations exist in which it would be desirable to provide quick and accurate access to information regarding various aspects of a scene of a fire.

[0004] Therefore, what is needed is systems and methods that facilitate communication of information at the scene of a fire.

SUMMARY OF THE INVENTION

[0005] According to a first preferred embodiment, a method comprises acquiring information pertaining to a scene of a fire. The acquiring step is performed by a sensor connected to a first computer. The method further comprises transmitting the information from the first computer to a second computer by way of a wireless communication network. The second computer is mounted to a fire fighting vehicle and is connected to a display. The method further comprises displaying the information at the fire fighting vehicle using the display.

[0006] According to a second preferred embodiment, a system comprises a wireless communication network and a plurality of fire fighting vehicles. The plurality of fire fighting vehicles include a respective plurality of on-board computer systems. Each one of the plurality of on-board computer systems is connected to remaining ones of the plurality of on-board computer systems by way of the wireless communication network.

[0007] According to a third preferred embodiment, a method comprises generating digital video information. The generating step is performed by a digital camera mounted on a first fire fighting vehicle. The method further comprises transmitting the digital video information from the first fire fighting vehicle to a second fire fighting vehicle over a wireless communication network that connects the first fire fighting vehicle and the second fire fighting vehicle. The digital video information comprises video images of a fire in progress. The method further comprises displaying the digital video information at the second fire fighting vehicle.

[0008] According to a fourth preferred embodiment, a system comprises a wireless communication network, a plurality of fire fighting vehicles, and a display. Each of the plurality of fire fighting vehicles comprises an on-board computer system and a camera capable of generating digital video information. The on-board computer system is connected to the wireless communication network. The camera is capable of generating digital video information and is connected to the wireless communication network by way of the on-board computer system. The is connected to the wireless communication network and is capable of receiving the digital video information over

the wireless communication network. The on-board computer system of each of the plurality of fire fighting vehicles is capable of transmitting the digital video information over the wireless communication network.

[0009] According to a fifth preferred embodiment, a system comprises a building monitoring system for a building and a fire fighting vehicle. The building monitoring system comprises a network of fire/smoke detection sensors distributed throughout the building, and a building computer system. The building computer system stores information pertaining to the building. The fire fighting vehicle has an on-board computer system and a display. The on-board computer system and the building computer system are capable of establishing a wireless network communication link to transfer the building information from the building computer system to the on-board computer system.

[0010] According to a sixth preferred embodiment, a real-time resource management method for managing resources of a plurality of fire fighting vehicles comprises acquiring resource supply information from the plurality of fire fighting vehicles and generating a display that provides comparative information regarding availability of resources on the fire fighting vehicles.

[0011] According to a seventh preferred embodiment, a method of displaying information pertaining to a fire comprises displaying a building map of a building that is a site of a fire in progress, displaying locations of a plurality of fire fighting vehicles relative to the building, displaying locations of active fire/smoke detection sensors inside the building, and displaying locations of firefighters inside the building. The locations of the fire fighting vehicles, the locations of the active fire/smoke detection sensors, and the locations of the firefighters are updated in real time during the fire in progress.

[0012] Other objects, features, and advantages of the present invention will become apparent to those skilled in the art from the following detailed description and accompanying drawings. It should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the present invention, are given by way of illustration and not limitation. Many modifications and changes within the scope of the present invention may be made

without departing from the spirit thereof, and the invention includes all such modifications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Fig. 1 is a schematic view of a fire truck having a control system according to one embodiment of the present invention;

[0014] Fig. 2 is a block diagram of the control system of Fig. 1 showing selected aspects of the control system in greater detail;

[0015] Fig. 3 is a schematic view of a military vehicle having a control system according to another embodiment of the present invention;

[0016] Figs. 4-5 are block diagrams of the control system of Fig. 3 showing selected aspects of the control system in greater detail;

[0017] Figs. 6A-6B are modified views of the block diagram of Fig. 5 showing the operation of the control system to reconfigure itself in a failure mode of operation;

[0018] Fig. 7 is a diagram showing the memory contents of an exemplary interface module in greater detail;

[0019] Fig. 8 is an overview of a preferred variant vehicle system;

[0020] Fig. 9 is a block diagram of the control system of Fig. 3 showing selected aspects of the control system in greater detail;

[0021] Fig. 10 is an I/O status table of Fig. 9 shown in greater detail;

[0022] Fig. 11 is a flowchart describing the operation of the control system of Fig. 9 in greater detail;

[0023] Fig. 12 is a data flow diagram describing data flow through an exemplary interface module during the process of Fig. 11;

[0024] Fig. 13 is a block diagram of a fire fighting system that includes multiple fire fighting vehicles and other systems according to another preferred embodiment of the present invention;

[0025] Fig. 14 is a block diagram showing one of the fire fighting vehicles of Fig. 13 in greater detail;

[0026] Fig. 15 is a diagram showing the operation of the system of Fig. 13;

[0027] Figs. 16-17 are flowcharts showing the operation of the system of Fig. 13 in greater detail;

[0028] Fig. 18 is an image displayed to a user of the system of Fig. 13;

[0029] Fig. 19 is a resource manager window generated using the system of Fig. 13;

[0030] Fig. 20 is a flowchart showing another aspect of the operation of the system of Fig. 13 in greater detail;

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] Patent application 09/384,393, filed August 27, 1999, allowed, discloses various embodiments of a control system architecture in connection with fire trucks, military vehicles and other types of vehicles. A particularly advantageous use of the preferred control system architecture is in the context of scene management for fire fighting vehicles. For convenience, the contents of the above-mentioned application is repeated below, followed by a description of scene management systems and methods which in a preferred embodiment use a control system of a type disclosed in the above-mentioned applications but which can also use other systems.

A. Fire Truck Control System

1. Architecture of Preferred Fire Truck Control System

[0032] Referring now to Fig. 1, a preferred embodiment of a fire truck 10 having a control system 12 is illustrated. By way of overview, the control system 12 comprises a central control unit 14, a plurality of microprocessor-based interface modules 20 and 30, a plurality of input devices 40 and a plurality of output devices 50. The central control unit 14 and the interface modules 20 and 30 are connected to each other by a communication network 60.

[0033] More specifically, the central control unit 14 is a microprocessor-based device and includes a microprocessor 15 that executes a control program 16 (see Fig. 2) stored in memory of the central control unit 14. In general, the control unit 14 executes the program to collect and store input status information from the input devices 40, and to control the output devices 50 based on the collected status information. The control program may implement an interlock system, a load manager, and a load sequencer. As described below, the central control unit 14 is preferably not connected to the I/O devices 40 and 50 directly but rather only indirectly by way of the interface modules 20 and 30, thereby enabling distributed data collection and power distribution. The I/O devices 40 and 50 are located on a chassis 11 of the fire truck 10, which includes both the body and the underbody of the fire truck 10.

[0034] In the illustrated embodiment, two different types of interface modules are used. The interface modules 20 interface mainly with switches and low power indicators, such as LEDs that are integrally fabricated with a particular switch and that are used to provide visual feedback to an operator regarding the state of the particular switch. For this reason, the interface modules 20 are sometimes referred to herein as "SIMs" ("switch interface modules"). Herein, the reference numeral "20" is used to refer to the interface modules 20 collectively, whereas the reference numerals 21, 22 and 23 are used to refer to specific ones of the interface modules 20.

[0035] The interface modules 30 interface with the remaining I/O devices 40 and 50 on the vehicle that do not interface to the interface modules 20, and therefore are sometimes referred to herein as "VIMs" ("vehicle interface modules"). The interface modules 30 are distinguishable from the interface modules 20 mainly in that the interface modules 30 are capable of handling both analog and digital inputs and outputs, and in that they are capable of providing more output power to drive devices such as gauges, valves, solenoids, vehicle lighting and so on. The analog outputs may be true analog outputs or they may be pulse width modulation outputs that are used to emulate analog outputs. Herein, the reference numeral "30" is used to refer to the interface modules 30 collectively, whereas the reference numerals 31, 32, 33, 34 and 35 are used to refer to specific ones of the interface modules 30.

[0036] Although two different types of interface modules are used in the illustrated embodiment, depending on the application, it may be desirable to use only a single type

of interface module in order to reduce inventory requirements. Additionally, while in Fig. 1 three of the interface modules 20 and five of the interface modules 30 are shown, this arrangement is again simply one example. It may be desirable to provide each interface module with more I/O points in order to reduce the number of interface modules that are required, or to use more interface modules with a smaller number of I/O points in order to make the control system 12 more highly distributed. Of course, the number of interface modules will also be affected by the total number of I/O points in the control system.

[0037] Figure 1 shows an approximate distribution of the interface modules 20 and 30 throughout the fire truck 10. In general, in order to minimize wiring, the interface modules 20 and 30 are placed so as to be located as closely as possible to the input devices 40 from which input status information is received and the output devices 50 that are controlled. As shown in Fig. 1, there is a large concentration of interface modules 20 and 30 near the front of the fire truck 10, with an additional interface module 34 at mid-length of the fire truck 10 and another interface module 35 at the rear of the fire truck 10. The large concentration of interface modules 20 and 30 at the front of the fire truck 10 is caused by the large number of switches (including those with integral LED feedback output devices) located in a cab of the fire truck 10, as well as the large number of other output devices (gauges, lighting) which tend to be located in the cab or otherwise near the front of the fire truck 10. The interface module 34 that is located in the middle of the truck is used in connection with I/O devices 40 and 50 that are located at the fire truck pump panel (i.e., the operator panel that has I/O devices for operator control of the fire truck's pump system). The interface module 35 that is located at the rear of the fire truck 10 is used in connection with lighting and other equipment at the rear of the fire truck 10.

[0038] The advantage of distributing the interface modules 20 and 30 in this manner can be more fully appreciated with reference to Fig. 2, which shows the interconnection of the interface modules 20 and 30. As shown in Fig. 2, the interface modules 20 and 30 receive power from a power source 100 by way of a power transmission link 103. The power transmission link 103 may comprise for example a single power line that is routed throughout the fire truck 10 to each of the interface modules 20 and 30. The interface modules then distribute the power to the output

devices 50, which are more specifically designated with the reference numbers 51a, 52a, 53a, 54a-c, 55a-c, 56a-b, 57a-c and 58a-d in Fig. 2.

[0039] It is therefore seen from Figs. 1 and 2 that the relative distribution of the interface modules 20 and 30 throughout the fire truck 10 in combination with the arrangement of the power transmission link 103 allows the amount of wiring on the fire truck 10 to be dramatically reduced. The power source 100 delivers power to the interface modules 20 and 30, which act among other things as power distribution centers, and not directly to the output devices 50. Because the interface modules 20 and 30 are located so closely to the I/O devices 40 and 50, most of the I/O devices can be connected to the interface modules 20 and 30 using only a few feet of wire or less. This eliminates the need for a wire harness that extends the length of the fire truck (about forty feet) to establish connections for each I/O devices 40 and 50 individually.

[0040] Continuing to refer to Fig. 2, the switch interface modules 20 and the interconnection of the interface modules 20 with various I/O devices will now be described in greater detail. The interface modules 20 are microprocessor-based, as previously noted, and include a microprocessor that executes a program to enable communication over the communication network 60, as detailed below.

[0041] The same or a different microprocessor of the interface modules 20 may also be used to process input signals received from the input devices 40. In particular, the interface modules 20 preferably perform debounce filtering of the switch inputs, so as to require that the position of the switch become mechanically stable before a switch transition is reported to the central control unit 14. For example, a delay of fifty milliseconds may be required before a switch transition is reported. Performing this filtering at the interface modules 20 reduces the amount of processing that is required by the central control unit 14 to interpret switch inputs, and also reduces the amount of communication that is required over the communication network 60 because each switch transition need not be reported.

[0042] Physically, the interface modules 20 may be placed near the headliner of a cab 17 of the fire truck 10. Traditionally, it is common practice to locate panels of switches along the headliner of the cab for easy access by an operator of the fire truck. Additionally, as detailed below, in the preferred embodiment, the interface modules 20

are connected to switches that have integrally fabricated LEDs for indicating the state of the output device controlled by the switch to provide maximum operator feedback. These LEDs are output devices which are connected to the interface modules 20. Therefore, by locating the interface modules near the headliner of the cab, the amount of wiring required to connect the interface modules 20 not only to the switches and but also to the LED indicators is reduced.

[0043] In the preferred embodiment, the interface modules 20 have between ten and twenty-five each of inputs and outputs and, more preferably, have sixteen digital (on/off switch) inputs and sixteen LED outputs. Most of these inputs and outputs are utilized in connection with switches having integrally fabricated LEDs. However, it should be noted that there need not be a one-to-one correspondence between the switches and the LEDs, and that the inputs and the outputs of the interface modules 20 need not be in matched pairs. For example, some inputs may be digital sensors (without a corresponding output device) and some of the outputs may be ordinary digital indicators (without a corresponding input device). Additionally, the LED indicators associated with the switch inputs for the interface module 21 could just as easily be driven by the interface module 23 as by the interface module 21, although this arrangement is not preferred. Of course, it is not necessary that all of the inputs and outputs on a given interface module 20 be utilized and, in fact, it is likely that some will remain unutilized.

[0044] One way of establishing a dedicated link between the I/O devices 40 and 50 and the interface modules 20 is through the use of a simple hardwired link. Considering for example an input device which is a switch, one terminal of the switch may be connected (e.g., by way of a harness connector) to an input terminal of the interface module 20 and the other terminal of the switch may be tied high (bus voltage) or low (ground). Likewise, for an output device which is an LED, one terminal of the LED may be connected to an output terminal of the interface module 20 and the other terminal of the LED may again be tied high or low. Other dedicated links, such as RF links, could also be used.

[0045] To provide maximum operator feedback, the LEDs that are located with the switches have three states, namely, off, on, and blinking. The off state indicates that the switch is off and therefore that the device controlled by the switch is off.

Conversely, the on state indicates that the switch is on and that the device controlled by the switch is on. The blinking state indicates that the control system 12 recognizes that a switch is on, but that the device which the switch controls is nevertheless off for some other reason (e.g., due to the failure of an interlock condition, or due to the operation of the load manager or load sequencer). Notably, the blinking LED feedback is made possible by the fact that the LEDs are controlled by the control unit 14 and not directly by the switches themselves, since the switches themselves do not necessarily know the output state of the devices they control.

[0046] Fig. 2 depicts one example of interconnection of input devices 40 (including input devices 41a, 41b, 42a, 42b, 43a, 43b, 44a, 45a, 46a, 46b, 47a, and 48a) and output devices 50 (including output devices 51a, 52a, 53a, 54a, 54b, 54c, 55a, 55b, 55c, 56a, 56b, 57a, 57b, 57c, 58a, 58b, 58c, 58d) to interface modules 20 and 30 (including interface modules 21, 22, 23, 31, 32, 33, 34 and 35). Many or all of the I/O devices 40 and 50 could be the same as those that have previously been used on fire trucks. Additionally, it should be noted that the example in Fig. 2 is just one example, and that a virtually unlimited number of configurations are possible.

[0047] Like the interface modules 20, the interface modules 30 are microprocessor-based and include a microprocessor that executes a program to enable communication over the communication network 60. The same or a different microprocessor of the interface modules 30 may also be used to process input signals received from the input devices 40 and to process output signals transmitted to the output devices 50. For the interface modules 30, this processing includes not only debounce filtering, in the case of switch inputs, but also a variety of other types of processing. For example, for analog inputs, this processing includes any processing that is required to interpret the inputs from analog-to-digital (A/D) converters, including converting units. For frequency inputs, this processing includes any processing that is required to interpret inputs from frequency-to-digital converters, including converting units. This processing also includes other simple filtering operations. For example, in connection with one analog input, this processing may include notifying the central control unit 14 of the status of an input device only every second or so. In connection with another analog input, this processing may include advising the central control unit 14 only when the status of the input device changes by a predetermined amount. For analog output devices, this processing includes any processing that is required to interpret the outputs for digital-

to-analog (D/A) converters, including converting units. For digital output devices that blink or flash, this processing includes implementing the blinking or flashing (i.e., turning the output device on and off at a predetermined frequency) based on an instruction from the central control unit 14 that the output device should blink or flash. In general, the processing by the interface modules 30 reduces the amount of information which must be communicated over the communication link, and also reduces the amount of time that the central control unit 14 must spend processing minor changes in analog input status.

[0048] Preferably, the configuration information required to implement the I/O processing that has just been described is downloaded from the central control unit 14 to each interface module 30 (and each interface module 20) at power-up. Additionally, the harness connector that connects to each of the interface modules 20 and 30 are preferably electronically keyed, such that being connected to a particular harness connector provides the interface modules 20 and 30 with a unique identification code (for example, by tying various connector pins high and low to implement a binary code). The advantage of this approach is that the interface modules 20 and 30 become interchangeable devices that are customized only at power-up. As a result, if one of the interface modules 30 malfunctions, for example, a new interface module 30 can be plugged into the control system 12, customized automatically at power-up (without user involvement), and the control system 12 then becomes fully operational. This enhances the maintainability of the control system 12.

[0049] The interface modules 20 and the interface modules 30 are connected to the central control unit 14 by the communication network 60. The communication network may be implemented using a network protocol, for example, which is in compliance with the Society of Automotive Engineers (SAE) J1708/1587 and/or J1939 standards. The particular network protocol that is utilized is not critical, although all of the devices on the network should be able to communicate effectively and reliably.

[0050] The transmission medium may be implemented using copper or fiber optic cable. Fiber optic cable is particularly advantageous in connection with fire trucks because fiber optic cable is substantially immune to electromagnetic interference, for example, from communication antennae on mobile news vehicles, which are common at the scenes of fires. Additionally, fiber optic cable is advantageous because it reduces RF emissions and

the possibility of short circuits as compared to copper-based networks. Finally, fiber optic cable is advantageous because it reduces the possibility of electrocution as compared to copper in the event that the cable accidentally comes into contact with power lines at the scene of a fire.

[0051] Also connected to the communication network 60 are a plurality of displays 81 and 82. The displays 81 and 82 permit any of the data collected by the central control unit 14 to be displayed to the firefighters in real time. In practice, the data displayed by the displays 81 and 82 may be displayed in the form of text messages and may be organized into screens of data (given that there is too much data to display at one time) and the displays 81 and 82 may include membrane pushbuttons that allow the firefighters to scroll through, page through, or otherwise view the screens of data that are available. Additionally, although the displays 81 and 82 are both capable of displaying any of the information collected by the central control unit 14, in practice, the displays 81 and 82 are likely to be used only to display selected categories of information. For example, assuming the display 81 is located in the cab and the display 82 is located at the pump panel, the display 81 is likely to be used to display information that pertains to devices which are controlled from within the cab, whereas the display 82 is likely to be used to display information pertaining to the operation of the pump panel. Advantageously, the displays 81 and 82 give firefighters instant access to fire truck information at a single location, which facilitates both normal operations of the fire truck as well as troubleshooting if problems arise.

[0052] Also shown in Fig. 2 is a personal computer 85 which is connected to the control unit 14 by way of a communication link 86, which may be a modem link, an RS-232 link, an Internet link, and so on. The personal computer 85 allows diagnostic software to be utilized for remote or local troubleshooting of the control system 12, for example, through direct examination of inputs, direct control of outputs, and viewing and controlling internal states, including interlock states. Because all I/O status information is stored in the central control unit 14, this information can be easily accessed and manipulated by the personal computer 85. If a problem is encountered, the personal computer can be used to determine whether the central control unit 14 considers all of the interface modules 20 and 30 to be "on-line" and, if not, the operator can check for bad connections and so on. If a particular output device is not working properly, the personal computer 85 can be used to trace the I/O status

information from the switch or other input device through to the malfunctioning output device. For example, the personal computer 85 can be used to determine whether the switch state is being read properly, whether all interlock conditions are met, and so on.

[0053] The personal computer 85 also allows new firmware to be downloaded to the control unit 14 remotely (e.g., from a different city or state or other remote location by way of the Internet or a telephone link) by way of the communication link 86. The firmware can be firmware for the control unit 14, or it can be firmware for the interface modules 20 and 30 that is downloaded to the control unit 14 and then transmitted to the interface modules 20 and 30 by way of the communication network 60.

[0054] Finally, referring back to Fig. 1, several additional systems are shown which will now be briefly described before proceeding to a discussion of the operation of the control system 12. In particular, Fig. 1 shows an engine system including an engine 92 and an engine control system 91, a transmission system including a transmission 93 and a transmission control system 94, and an anti-lock brake system including an anti-lock brake control system 95 and anti-lock brakes 96. The transmission 93 is mechanically coupled to the engine 92, and is itself further mechanically coupled to a PTO system 97. The PTO system 97 allows mechanical power from the engine to be diverted to water pumps, aerial drive mechanisms, stabilizer drive mechanisms, and so on. In combination, the engine system, the transmission system and the PTO system form the power train of the fire truck 10.

[0055] The control systems 92, 94 and 95 may be connected to the central control unit 14 using the same or a different communication network than is used by the interface modules 30 and 40. In practice, the control systems 92, 94 and 95 are likely to be purchased as off-the-shelf systems, since most fire truck manufacturers purchase rather than manufacture engine systems, transmission systems and anti-lock brake systems. As a result, it is likely that the control systems 92, 94 and 95 will use a variety of different communication protocols and therefore that at least one additional communication network will be required.

[0056] By connecting the systems 92, 94 and 95 to the central control unit 14, an array of additional input status information becomes available to the control system 12. For example, for the engine, this allows the central control unit 14 to obtain I/O status

information pertaining to engine speed, engine hours, oil temperature, oil pressure, oil level, coolant level, fuel level, and so on. For the transmission, this allows the central control unit 14 to obtain, for example, information pertaining transmission temperature, transmission fluid level and/or transmission state (1st gear, 2nd gear, and so on). Assuming that an off-the-shelf engine or transmission system is used, the information that is available depends on the manufacturer of the system and the information that they have chosen to make available.

[0057] Connecting the systems 92, 94 and 95 to the central control unit 14 is advantageous because it allows information from these subsystems to be displayed to firefighters using the displays 81 and 82. This also allows the central control unit 14 to implement various interlock conditions as a function of the state of the transmission, engine or brake systems. For example, in order to turn on the pump system (which is mechanically driven by the engine and the transmission), an interlock condition may be implemented that requires that the transmission be in neutral or 4th lockup (i.e., fourth gear with the torque converter locked up), so that the pump can only be engaged when the wheels are disengaged from the power train. The status information from these systems can therefore be treated in the same manner as I/O status information from any other discrete I/O device on the fire truck 10. It may also be desirable to provide the central control unit 14 with a limited degree of control over the engine and transmission systems, for example, enabling the central control unit 14 to issue throttle command requests to the engine control system 91. This allows the central control unit to control the speed of the engine and therefore the voltage developed across the alternator that forms part of the power source 100.

2. Scene Management

[0058] Referring now to Fig. 13, a fire fighting system 110 in accordance with another preferred aspect of the invention is shown. The system 110 comprises a plurality of fire trucks 111-114, a central dispatch station 116, and a wireless communication network 120 which connects the fire trucks 111-114 and the central dispatch station 116. Also shown is a building 117, which is assumed to be the scene of a fire, as well as a pair of firefighters 118-119 who are assumed to be located inside the building 117. Of course, although four fire trucks and two firefighters are shown, it is also possible to use the system 110 in conjunction with fewer or additional fire

trucks and/or firefighters. Also, although in the preferred embodiment the fire fighting system 110 includes all of the devices shown in Fig. 13, it is also possible to construct a fire fighting system that only uses some of the devices shown in Fig. 13.

[0059] The fire trucks 111-114 are each constructed in generally the same manner as the fire truck 10 previously described, and therefore each have a control system 12 or 1412 as previously described in connection with Figs. 1-12. The fire trucks 111-114 each further include a digital camera 126, a speaker/microphone system 127, a display 128, resource monitoring sensors 130, hazardous material sensors 132, and wind speed/direction sensors 134. Although these features are described in connection with the fire truck 111 in Fig. 13, it should be noted that the fire trucks 112-114 include these features as well.

[0060] Referring now also to Fig. 14, the fire truck 111 is shown in greater detail. The computer system 124 may be implemented using a single computer, but is preferably implemented using a computer 125 in combination with one or more of the interface modules 30 previously described in connection with Figs. 1-2. In this regard, it may be noted that the sensors 130-134 are preferably specific ones of the sensors 44a, 45a, 46a, 47a, and 48a that are connected to the interface modules 31-35 as previously described. The sensors 130-134 are therefore connected to the interface module (or modules) 30 which in turn is connected to the communication network 60. The computer 125 is also connected to the communication network 60 along with the interface modules 20 and 30 and therefore is able to receive data from anywhere in the control system 12. Assuming a single central control unit 14 is used as described in connection with Figs. 1-2, data is received by the computer 125 from the interface modules 20 and 30 by way of the central control unit 14. Alternatively, if a distributed control scheme is used as described in connection with Figs. 3-12, then data may be received directly from the interface modules 20 and 30.

[0061] The resource monitoring sensors 130 further include a water level sensor 136, an oxygen level sensor 138, a fuel level sensor 140, and a foam agent sensor 142. The water level sensor 136 monitors the amount of water in an on-board storage tank (not shown) available to be pumped and dispensed on the fire in progress. The oxygen level sensor 138 monitors the amount of oxygen available for life support systems for firefighters in or near the scene of the fire. The fuel level sensor 140

monitors the amount of fuel available for the engine 92 of the fire truck 10. The foam agent sensor 142 monitors the amount of foam agent available to be dispensed on the fire in progress. Other sensors that monitor the levels of other consumable resources may also be provided.

[0062] In addition to the resource monitoring sensors 130, the hazardous material sensors 132 and the wind speed/direction sensors 134 are also provided. The hazardous material sensors 132 include sensors that monitor the air for hazardous materials combusting or emitted from the fire. The wind speed/direction sensors 134 include one or more sensors that in combination measure wind speed and direction.

[0063] The computer 125 is connected to the communication network 60 along with the interface modules 20 and 30 and itself serves as an additional interface module. The computer 125 is different than the interface modules 20 and 30 in that the computer 125 has enhanced graphics capability to permit the computer 125 to interface with video I/O devices, specifically, an input device in the form of the digital camera 126 and an output device in the form of the display 128. The computer 125 is capable of receiving streaming digital video information from the digital camera 126 and using the digital information, as well as information from other sources, to drive the display 128. The digital camera 126 may be any device that is capable of generating digital video information. Preferably, the digital camera 126 is a ruggedized webcam and is mounted at a location on the fire truck 111 that permits a clear view of the fire to be developed, for example, on the roof of the fire truck 111 or at the end of an aerial of the fire truck 111. The display 128 is connected to the wireless communication network 120 by way of the computer 125 and receives digital video information from the communication network 120 by way of the computer 125. The display 128 is preferably a ruggedized, flat panel touch screen SVGA display or better, allowing for the display of high resolution streaming video information on-board the fire truck 111. The display 128 may be mounted in an operator compartment or on the side of the fire truck 111, for example. The computer 125 is preferably also connected to a speaker/microphone system 127 which comprises a microphone and a speaker system that are connected to the computer 125, e.g., by way of a sound card. The speaker/microphone system 127 is used to acquire and communicate voice information over the communication network 120, as detailed below.

[0064] The computer 125 is connected to a wireless modem 143 which connects the computer 125 to the communication network 120. Preferably, the communication network 120 is implemented using the internet and the wireless modem 143 connects the computer 125 to a secure area of the world wide web ("the web"). The wireless modem 143 is a cellular telephone modem and connects the computer 125 to the internet by way of a wireless telephone link to an internet service provider. The cellular telephone service used in this regard services the geographic region which includes the building 117 and preferably services the entire municipal region serviced by the fire trucks 111-114. In practice, it may be desirable to use multiple cellular telephone modems operating in parallel at each vehicle to obtain additional bandwidth to permit the computer 125 to receive and display high resolution video information from the other fire trucks 112-114 in real time. Alternatively, a high bandwidth internet connection could also be established by establishing respective satellite links between the fire trucks 111-114 and an internet-enabled based station. Other forms of high bandwidth wireless networks may also be used, including network links that do not involve the internet.

[0065] Finally, the computer 125 is connected to the global positioning system (GPS) receiver 135. The GPS receiver 135 provides the computer 125 with pinpoint coordinates regarding the location of the fire truck 111.

[0066] Referring back to Fig. 13, the central dispatch station 116 further includes a central dispatch computer system 146 and a display 148. The central dispatch station 116 coordinates deployment of fire trucks vehicles to fires. The central dispatch station 116 is connected to the communication network 120 and receives information from the fire trucks 111-114 and the building 117 as described below. The display 148 is connected to the communication network 120 by way of the dispatch computer system 146 and receives digital video information from the communication network 120 by way of the dispatch computer system 146.

[0067] The building 117 comprises a building monitoring system 150 which further includes a building computer system 151 and a fire/smoke detection system 152. The building computer system 150 has stored therein building map information 154 and data 156 describing the storage locations of hazardous materials throughout the building 117. The fire/smoke detection system 152 comprises a plurality of fire/smoke

detection sensors 157 and 158 (see Fig. 15) distributed throughout the building 117. Herein, a "fire/smoke detection sensor" is a sensor that is capable of detecting fire and/or smoke.

[0068] The building map information 154 may simply comprise a digitized form of the architectural plans for the building 117. Preferably, however, the building map information 154 is provided in a simplified format that shows only the basic layout of the building 117. Preferably, the building map information 154 also includes a plurality of GPS waypoints which pinpoint fiducial locations in the building 117 to permit registration of the building map information 154 with location information acquired from other GPS devices. In particular, the GPS coordinates are preferably used to relate specific locations shown on the building map to specific lateral/longitudinal coordinates, so that images of other objects having known GPS coordinates (such as the fire trucks 111-114 and the firefighters 118-119) superimposed on to the building map information 154, as detailed below.

[0069] Rather being stored in the building computer system 151, the building map information may alternatively be stored in the dispatch computer system 146 and/or in the computer systems 124 and 160. In this regard, it may be noted that most municipalities require that building plans be on file with the municipality. Therefore, it may be preferable as a practical matter to ensure that appropriate electronic building plans are also in place for all buildings in a municipality before a fire occurs. If necessary, simplified building maps may be generated based upon paper copies of on-file building plans, especially since only the most basic building plan information is used in the system 110.

[0070] The hazardous material information 156 comprises information which pertains to the types of hazardous materials located in the building 117 and information which pertains to the locations of the various types of hazardous materials in the building 117. Often, hazardous materials are stored in known production areas or in designated storage areas, and the hazardous material information may comprise the locations of these areas. Alternatively, containers that store the hazardous materials may be provided with position transponders to permit the location of the containers to be tracked in real time. In this event, the transponders are preferably provided with unique identifying codes to identify the container and thereby identify the hazardous material in

the container as well as other specifics (e.g., amount, type, toxicity, volatility, age, and so on).

[0071] The firefighters 118-119 are assumed to be inside the building 117. As with the fire trucks 111-114, the firefighters 118-119 are provided with generally the same equipment even though only the firefighter 118 is shown in detail. The firefighter 118 is provided with a computer system 160, a digital camera 162, a microphone/speaker system 164, a display 166, a GPS receiver 168 and an oxygen sensor 170. Preferably, the devices 160-170 are lightweight, ruggedized, and integrally provided in the form of an intelligent helmet. The computer system 160 is connected to the communication network 120 by way of a cellular telephone modem as previously described in connection with the computer 125. The digital camera 162 is preferably mounted to provide a view of the fire in progress as seen by the firefighter 118. The microphone/speaker system 164 is mounted in the helmet and allows for voice communication with the firefighter 118 over the communication network 120. The display 166 may be provided in the form of a transparent eye piece which allows for the injection of video into the eye piece, such that the firefighter 118 can simultaneously view the video information as well as the firefighter's own surroundings (akin to night vision equipment). Alternatively, the display 158 may be provided in the form of a heads-up display in which video information is projected onto a visor of the helmet. Other arrangements may also be used, such as a small flat panel display mounted on an exterior surface of an arm panel of the firefighter's protective clothing. The GPS receiver 168 provides the computer 160 with the real time coordinates of the firefighter 118 inside the building 117, thereby allowing the firefighter's location to be transmitted over the communication network 120. Finally, the oxygen sensor 170 is also connected to the computer system 160 and permits the oxygen supply level available to the firefighter 118 to be broadcast over the communication network 120. Of course, other sensors could also be mounted in the helmet or elsewhere with the firefighter and used to broadcast information over the communication network 120.

[0072] Referring now to Figs. 15-18, the operation of the system of Fig. 13 will now be described. Figure 15 shows a simplified plan view of the building 117 (including interior office space, meeting rooms, corridors, laboratories, and/or warehouse space) which is assumed to be located at the scene of a fire. The fire trucks 111-114 as well as the firefighters 118-119 are located around the perimeter of the building 117 to fight

the fire. In Fig. 15, only about one-half of one floor of the building 117 is shown, however, the building 117 is also shown on the display 128. The fire truck 114 is located at a position that cannot be seen in Fig. 15 except on the display 128.

[0073] Figures 16-17 are flowcharts that describe the operation of the system of Fig. 13 in the context of the scene of Fig. 15. With reference to Fig. 16-17, Fig. 16 shows the operation of the building computer system 151. It may be noted that, although the steps are shown in a particular order in Fig. 16, there is no need for the steps to be performed in the order shown.

[0074] When a fire breaks out at the building 117, the fire is detected at step 175 by the building computer system 151 using the fire/smoke detection system 152. At step 176, the building computer system 151 contacts the local fire department, and in response the fire trucks 111-114 and firefighters 118-119 are deployed to the scene of the fire. At step 177, the building computer system 152 transmits the building map information 154 to the fire trucks 111-114, the central dispatch station 116, and the firefighters 118-119 by way of the communication network 120. For example, in the context of a municipal fire department, fire department officials may coordinate with the owners of local businesses and other buildings to ensure that the building computer system 151 is provided with e-mail an address for the dispatch computer system 146, which can then forward the building map information 154 to the computer systems 124 and 160. Alternatively, the building map information 154 and may be transmitted to the computer systems 124 and 160 directly, or may already be stored in the computer systems 124 and 160.

[0075] At step 178, the building computer system 151 transmits hazardous material information 156 to the fire trucks 111-114, the central dispatch station 116, and the firefighters 118-119 by way of the communication network 120. At step 179, the building computer system 151 transmits information from the fire/smoke detection system 152 to the fire trucks 111-114, the central dispatch station 116, and the firefighters 118-119 by way of the communication network 120. Again, the transmissions in steps 178 and 179 may occur either directly or indirectly by way of the dispatch station 116. Steps 178 and 179 are thereafter repeated at regular intervals throughout the duration of the fire or as long as the computer system 151 remains operational. (In this regard, it may be noted that, other than the sensors 157

and 158, some or all of the computer system 151 may be located off-site, thereby allowing the computer system 151 to remain operational throughout the duration of the fire.) Because the steps 178 and 179 are repeated at regular intervals, the fire trucks 111-114 and firefighters 118-119 are provided with information updated in real time pertaining to the locations of active fire/smoke detection sensors and the locations of hazardous materials (in the case where position transponders are used) inside the building at the scene of the fire.

[0076] With reference to Fig. 17, Fig. 17 shows the operation of the computer systems 124, 146, and 160. Again, although the steps are shown in a particular order in Fig. 17, there is no need for the steps to be performed in the order shown. After the fire breaks out, the computer systems 124, 146, and 160 receive the building map information 154 from the building monitoring system at step 180. At step 181, the computer systems 124, 146, and 160 receive updated information from the fire/smoke detection system 152 and updated hazardous material information 156.

[0077] At step 182, the computer systems 124 and 160 transmit audio-visual information, GPS location information, and resource information to other ones of the fire trucks 111-114 and the firefighters 118-119 by way of the communication network 120. It may be noted that the dispatch computer 146 does not perform step 182 in the illustrated embodiment. For the fire trucks 111-114, the transmitted audio-visual information includes digital image information acquired by the digital camera 126 and digital voice information acquired by the speaker/microphone system 127, the transmitted GPS information includes the GPS coordinates acquired by the GPS receivers 133, and the transmitted resource information includes the information generated by the resource monitoring sensors 130. For the firefighters 118-119, the transmitted audio-visual information includes digital image information acquired by the digital camera 162 and digital voice information acquired by the speaker/microphone system 164, the transmitted GPS information includes the GPS coordinates acquired by the GPS receiver 168, and the transmitted resource information includes information generated by the oxygen sensor 170.

[0078] At step 183, the computer systems 124, 146 and 160 receive the audio-visual information, GPS location information, and resource information from the other ones of the fire trucks 111-114 and firefighters 118-119 transmitted in step 182. At

step 184, the computer systems 124, 146 and 160 drive the displays 128, 148 and 166, respectively, to display some or all of the information received at step 183.

[0079] Figure 15 shows an image 186 generated by the display 128 of the fire truck 111 and displayed to an operator of the fire truck 111. Although the image is shown as being generated at the fire truck 111, the same or similar images are preferably also at the remaining fire trucks 112-114 and/or at the dispatch station 116. The same image could also be generated for the firefighters 118-119 by the display 166, however, it is preferred that the firefighters 118-119 be provided with a more simplified image as detailed below.

[0080] The image 186 includes multiple views 187 of the fire in progress. The views 187 may be displayed based on digital video information generated by the digital cameras 126 of any of the fire trucks 111-114 and/or based on digital video information generated by the digital cameras 162. Therefore, the operator of the fire trucks 111-114 and/or the dispatcher at the dispatch station 116 is provided with the ability to view the scene of the fire from multiple vantage points at a single, potentially remotely-located display.

[0081] The image 186 also includes the building map information 154 received from the building computer system 151. The portion of the image 186 that includes the building map information as well as other information is shown in greater detail in Fig. 18. Referring now also to Fig. 18, the image 186 includes a plurality of icons used to display additional information to the operator. The computer 125 uses the GPS coordinates received from the GPS receivers 133 and 168 as previously described to display the icons simultaneously with the building map information 154, thereby displaying an enhanced building map that provides an overall indication of the relative locations of various components of the fire fighting system 110. Specifically, the image 186 includes icons 111a-114a that display the locations of the fire trucks 111-114, respectively, relative to the building 117. The image 186 also includes icons 111a-114a that display the locations of the fire trucks 111-114, respectively. The image 186 also includes icons 157a that indicate which ones of the fire/smoke detection sensors 157 are active (that is, are in a state that indicates that fire or smoke has been detected) and where the active sensors 157 are located. The image 186 also

includes icons 159a that display the locations of the hazardous materials 159 located in the building 117.

[0082] The computer systems 124 and 146 are preferably provided with web browser interfaces, thereby allowing the operator to obtain additional, more detailed information by clicking on or touching (in the case of a touch screen interface) various portions of the image. The computer systems 124 and 146 then modify the image 186 in response to receiving the operator input. For example, as shown in Fig. 18, the operator is able to click on the icon 113a representing the fire truck 113 to display resource levels acquired by the resource monitoring sensors 130. Additionally, with reference to Fig. 18, when the operator clicks on the icon 113a for the fire truck 113, one of the views 187 changes so as to be supplied with digital video information supplied by the digital camera 126 mounted on the fire truck 113. In connection with the firefighters 118 and 119, the operator is able to click on the icons 118a and 119a to have the digital video information from the digital camera 162 displayed on the image 186, and to have an information displayed pertaining to the amount of oxygen remaining as detected by the oxygen level sensor 170. The operator is also able to click on one of the icons 118a-119a to establish a private voice communication link with the respective firefighter 118-119 to permit a particularly urgent message to be communicated to the firefighter 118-119 without the firefighter 118-119 being distracted by other voice traffic. The operator is also able to click on one of the icons 159a representing the hazardous material to find out additional information regarding the hazardous material, such as information pertaining to the amount, type, toxicity, volatility, age, and so on of the hazardous material. Some of this information may also be communicated by adjusting the appearance of the icon 159a (e.g., the icons 159a may be formed of different letters to represent different types of hazardous materials). The operator can also click on one of the views 187 to have the view displayed in a larger format.

[0083] It is therefore seen that a tremendous amount of detailed information regarding the scene of the fire is easily accessible to the operator of the fire trucks 111-114 and the dispatcher at the dispatch station 116. This information can be used to facilitate resource deployment decisions. For example, in Fig. 18, the fire chief may decide to move the fire truck 112 to a position between the fire trucks 111 and 114, since the information in Fig. 18 indicates that more resources are needed on the other

side of the building 117. This is especially the case because the locations of hazardous materials inside the building 117 are known, and it may be possible to fight the fire in a manner that prevents the fire from spreading to portions of the building 117 that store hazardous materials. Alternatively, depending on the situation, it may be possible to deploy firefighters to extricate stored hazardous materials from the building 117. Such a dangerous activity, if undertaken, can be carefully monitored in real time from the fire trucks 111-114 or the dispatch station 116 because the locations of the firefighters 118-119, the locations of active fire/smoke detection sensors 157, and the locations of the hazardous materials can be monitored in real time. Therefore, firefighter safety and fire fighting effectiveness are improved.

[0084] As previously noted, the fire trucks 111-114 are provided with the microphone/speaker systems 127 and the firefighters are provided with the microphone/speaker systems 164 that are used to acquire and exchange voice data. Preferably, the icons 111a-114a and 118a-119a are displayed differently (i.e., highlighted) when voice data is received from the respective fire truck 111-114 or the respective firefighter 118a-119a. As a result, when an operator of the fire truck 111 is listening to voice data come over the speaker system 127, for example, the image 186 provides the operator with an indication of which firefighter or fire truck operator is talking by highlighting the appropriate icon 111a-114a and 118a-119a. Additionally, by clicking on the appropriate firefighter icon 118a-119a, it is possible to also view the digital video information acquired by the digital camera 162 carried by the firefighter 118 or 119, and thereby view the scene of the fire from the perspective of the firefighter inside the building. This arrangement therefore greatly enhances improves the ability to communicate with firefighters located inside the building 117 at the scene of the fire, and therefore further improves firefighter safety and effectiveness.

[0085] In addition to displaying resource information for one fire truck/firefighter at a time, it may also be desirable to provide a resource manager window as shown in Fig. 19. Referring now to Fig. 19, the resource manager 189 is executed by the computer systems 124 and 146 and displayed on the displays 128 and 148. The resource manager displays information regarding levels of consumable resources available as indicated by the sensors 130 and 170. The information is displayed in the form of a chart with the consumable resource levels of each of the fire trucks 111-114 and firefighters 118-119 being displayed in the form of amount of time remaining

before the consumable resource is completely depleted. Therefore, it is possible for a fire chief, dispatcher or other responsible party to quickly assess system status and determine when/where reinforcement resources will be required.

[0086] As previously noted, the same information that is transmitted to the fire trucks 111-114 is preferably also transmitted to the firefighters 118-119 inside the building 117. The image displayed to the firefighters 118-119 may be the same as the image 186 displayed to the operator of the fire trucks 111-114. The firefighters 118-119 are therefore provided with building map information for the building 117. Additionally, the firefighters 118-119 are also provided with a superimposed indication of their current position (updated in real time) inside the building 117 as well as a superimposed indication of the location (also updated in real time) of active fire/smoke detection sensors 157. Advantageously, this arrangement increases firefighter safety and effectiveness by allowing the firefighters 118-119 to navigate the building 117 more safely and with greater ease.

[0087] Preferably, the computer system 160 is equipped with voice recognition software to permit the computer system 160 to adjust the image displayed to the firefighter 118 in response to voice commands. The voice command interface may be used in lieu of the point and click operator interface or touch screen interface described above and to cause the computer system 160 to perform other specific tasks. For example, when the firefighter wishes to exit the building 117, the firefighter 118 is provided with the ability to issue a voice command to the computer system 160 (such as "find the nearest exit"). The computer system 160 then executes a pre-stored exit-finding algorithm to determine the nearest safe exit (taking into account active or previously active fire alarms) and displays a series of arrows that guide the firefighter 118 to the exit. The arrows are preferably provided with a 3-D appearance such that the arrows appear closer as the firefighter 118 approaches the point at which a right/left turn is required. More complicated direction-giving schemes could also be used. For example, the entire interior of the building 117 may be displayed in 3-D format, such that structures in the building 117 are seen to move past the firefighter 118 as the firefighter 118 progresses through the building (in a manner akin to modern virtual reality video games), thereby allowing particular doors to be highlighted by the computer system 160 as the firefighter 118 moves through the building 117. This approach, however, is not preferred.

[0088] The communication network 120 may also be used to communicate emergency information to the general public. For example, with reference to Fig. 20, evacuation information may be communicated. Thus, at step 191 of Fig. 20, data is acquired from hazardous material sensors 132. At step 192, wind speed/direction data is acquired from sensors 134. Preferably, step 191 is performed over several minutes to obtain not just instantaneous wind speed but also a profile of wind gusts. At step 193, the computer system 124 receives pinpoint location and time information describing the time at which the hazardous materials began to be spread and the source location. This information, for example, may be manually entered by an operator. At step 194, a rate of movement of the hazardous materials is computed based on the wind speed and direction. At step 195, a map is generated showing a tentative evacuation region. At step 196, an electronic alert message is sent to residents of the geographic area to advise the residents of the threat of the hazardous material. The electronic alert message (e.g., an e-mail message) may be used to complement other forms of communication (e.g., a siren) to provide residents with more detailed information as to the nature of the threat and/or written instructions as to how to proceed.

[0089] The preferred fire fighting system 110 therefore also improves community safety. As previously discussed, in situations where the scene of the fire stores hazardous materials, community safety is improved because the firefighters are provided with more information regarding the location, types, amounts and so on of hazardous materials at the scene of the fire and therefore are better able to tailor their fire fighting efforts to prevent the release of hazardous materials into the atmosphere. Additionally, in situations where hazardous materials are released, citizens are provided with better information regarding the nature of the threat and therefore are more likely to respond appropriately.

3. Additional Aspects

[0090] From the foregoing description, a number advantages of the preferred fire truck control system are apparent. In general, the control system is easier to use, more flexible, more robust, and more reliable than existing fire truck control systems. In addition, because of these advantages, the control system also increases firefighter safety because the many of the functions that were previously performed by firefighters are

performed automatically, and the control system also makes possible features that would otherwise be impossible or at least impractical. Therefore, firefighters are freed to focus on fighting fires.

[0091] The control system is easier to use because the control system provides a high level of cooperation between various vehicle subsystems. The control system can keep track of the mode of operation of the fire truck, and can control output devices based on the mode of operation. The functions that are performed on the fire truck are more fully integrated to provide a seamless control system, resulting in better performance.

[0092] For example, features such as load management and load sequencing are implemented in the control program executed by the central control unit. No additional hardware is required to implement load management and load sequencing. Therefore, if it is desired to change the order of load sequencing, all that is required is to modify the control program. It is also possible to have different load sequencing defined for different modes of operation of the vehicle with little or no increase in hardware. The manner in which load management is performed can also be changed dynamically during the operation of the fire truck.

[0093] The control system is robust and can accept almost any new feature without changes in wiring. Switches are connected to a central control unit and not to outputs directly, and new features can be programmed into the control program executed by the central control unit. A system can be modified by adding a new switch to an existing interface module, or by modifying the function of an existing switch in the control program. Therefore, modifying a system that is already in use is easy because little or no wiring changes are required.

[0094] Additionally, because the control system has access to input status information from most or all of the input devices on the fire truck and has control over most or all of the output devices on the fire truck, a high level of cooperation between the various subsystems on the fire truck is possible. Features that require the cooperation of multiple subsystems are much easier to implement.

[0095] The fire truck is also easier to operate because there is improved operator feedback. Displays are provided which can be used to determine the I/O status of any

piece of equipment on the vehicle, regardless of the location of the display. Additionally, the displays facilitate troubleshooting, because troubleshooting can be performed in real time at the scene of a fire when a problem is occurring. Troubleshooting is also facilitated by the fact that the displays are useable to display all of the I/O status information on the fire truck. There is no need for a firefighter to go to different locations on the fire truck to obtain required information. Troubleshooting is also facilitated by the provision of a central control unit which can be connected by modem to another computer. This allows the manufacturer to troubleshoot the fire truck as soon as problems arise.

[0096] LED indicators associated with switches also improve operator feedback. The LEDs indicate whether the switch is considered to be off or on, or whether the switch is considered to be on but the output device controlled by the switch is nevertheless off due to some other condition on the fire truck.

[0097] Because the control system is easier to use, firefighter safety is enhanced. When a firefighter is fighting fires, the firefighter is able to more fully concentrate on fighting the fire and less on having to worry about the fire truck. To the extent that the control system accomplishes tasks that otherwise would have to be performed by the firefighter, this frees the firefighter to fight fires.

[0098] The control system is also more reliable and maintainable, in part because relay logic is replaced with logic implemented in a control program. The logic in the control program is much easier to troubleshoot, and troubleshooting can even occur remotely by modem. Also mechanical circuit breakers can be replaced with electronic control, thereby further reducing the number of mechanical failure points and making current control occur more seamlessly. The simplicity of the control system minimizes the number of potential failure points and therefore enhances reliability and maintainability.

[0099] The system is also more reliable and more maintainable because there is less wire. Wiring is utilized only to established dedicated links between input/output devices and the interface module to which they are connected. The control system uses distributed power distribution and data collecting. The interface modules are interconnected by a network communication link instead of a hardwired link, thereby

reducing the amount of wiring on the fire truck. Most wiring is localized wiring between the I/O devices and a particular interface module.

[0100] Additionally, the interface modules are interchangeable units. In the disclosed embodiment, the interface modules 20 are interchangeable with each other, and the interface modules 30 are interchangeable with each other. If a greater degree of interchangeability is required, it is also possible to use only a single type of interface module. If the control system were also applied to other types of equipment service vehicles (e.g., snow removal vehicles, refuse handling vehicles, cement/concrete mixers, military vehicles such as those of the multipurpose modular type, on/off road severe duty equipment service vehicles, and so on), the interface modules would even be made interchangeable across platforms since each interface module views the outside world in terms of generic inputs and outputs, at least until configured by the central control unit. Because the interface modules are interchangeable, maintainability is enhanced. An interface module that begins to malfunction due to component defects may be replaced more easily. On power up, the central control unit downloads configuration information to the new interface module, and the interface module becomes fully operational. This enhances the maintainability of the control system.

[0101] Because the interface modules are microprocessor-based, the amount of processing required by the central control unit as well as the amount of communication that is necessary between the interface modules and the central control unit is reduced. The interface modules perform preprocessing of input signals and filter out less critical input signals and, as a result, the central control unit receives and responds to critical messages more quickly.

B. Military Vehicle Control System

[0102] Referring now to Fig. 3, a preferred embodiment of a military vehicle 1410 having a control system 1412 is illustrated. As previously indicated, the control system described above can be applied to other types of equipment service vehicles, such as military vehicles, because the interface modules view the outside world in terms of generic inputs and outputs. Most or all of the advantages described above in the context of fire fighting vehicles are also applicable to military vehicles. As previously described, however, it is sometimes desirable in the context of military applications for the military vehicle control system to be able to operate at a maximum level of

effectiveness when the vehicle is damaged by enemy fire, nearby explosions, and so on. In this situation, the control system 1412 preferably incorporates a number of additional features, discussed below, that increase the effectiveness of the control system 1412 in these military applications.

[0103] By way of overview, the control system 1412 comprises a plurality of microprocessor-based interface modules 1420, a plurality of input and output devices 1440 and 1450 (see Fig. 4) that are connected to the interface modules 1420, and a communication network 1460 that interconnects the interface modules 1420. The control system 1412 preferably operates in the same manner as the control system 12 of Figs. 1-2, except to the extent that differences are outlined are below. A primary difference between the control system 12 and the control system 1412 is that the control system 1412 does not include a central control unit that is implemented by a single device fixed at one location. Rather, the control system 1412 includes a central control unit that is allowed to move from location to location by designating one of the interface modules 1420 as a "master" interface module and by further allowing the particular interface module that is the designated master interface module to change in response to system conditions. As will be detailed below, this feature allows the control system 1412 to operate at a maximum level of effectiveness when the military vehicle 1410 is damaged. Additional features that assist failure management are also included.

[0104] More specifically, in the illustrated embodiment, the control system 1412 is used in connection with a military vehicle 1410 which is a multipurpose modular military vehicle. As is known, a multipurpose module vehicle comprises a chassis and a variant module that is capable of being mounted on the chassis, removed, and replaced with another variant module, thereby allowing the same chassis to be used for different types of vehicles with different types of functionality depending on which variant module is mounted to the chassis. In the illustrated embodiment, the military vehicle 1410 is a wrecker and includes a wrecker variant module 1413 mounted on a chassis (underbody) 1417 of the military vehicle 1410. The weight of the variant module 1413 is supported by the chassis 1417. The variant module 1413 includes a mechanical drive device 1414 capable of imparting motion to solid or liquid matter that is not part of the military vehicle 1410 to provide the military vehicle 1410 with a particular type of functionality. In Fig. 3, where the variant module 1413 is a wrecker variant, the

mechanical drive device is capable of imparting motion to a towed vehicle. As shown in Fig. 8, the variant module 1413 is removable and replaceable with other types of variant modules, which may include a dump truck variant 1418a, a water pump variant 1418b, a telephone variant 1418c, and so on. Thus, for example, the wrecker variant 1413 may be removed and replaced with a water pump variant 1418b having a different type of drive mechanism (a water pump) to provide a different type of functionality (pumper functionality). The I/O devices 1440 and 1450 used by the vehicle 1410 include devices that are the same as or similar to the non-fire truck specific I/O devices of Figs. 1-2 (i.e., those types of I/O devices that are generic to most types of vehicles), as well as I/O devices that are typically found on the specific type of variant module chosen (in Fig. 3, a wrecker variant).

[0105] The interface modules 1420 are constructed in generally the same manner as the interface modules 20 and 30 and each include a plurality of analog and digital inputs and outputs. The number and type of inputs and outputs may be the same, for example, as the vehicle interface modules 30. Preferably, as described in greater detail below, only a single type of interface module is utilized in order to increase the field serviceability of the control system 1412. Herein, the reference numeral 1420 is used to refer to the interface modules 1420 collectively, whereas the reference numerals 1421-1430 are used to refer to specific ones of the interface modules 1420. The interface modules are described in greater detail in connection with Figs. 4-7.

[0106] Also connected to the communication network 1460 are a plurality of displays 1481 and 1482 and a data logger 1485. The displays 1481 and 1482 permit any of the data collected by the control system 1412 to be displayed in real time, and also display warning messages. The displays 1481 and 1482 also include membrane pushbuttons that allow the operators to scroll through, page through, or otherwise view the screens of data that are available. The membrane pushbuttons may also allow operators to change values of parameters in the control system 1412. The data logger 1485 is used to store information regarding the operation of the military vehicle 1410. The data logger 1485 may also be used as a "black box recorder" to store information logged during a predetermined amount of time (e.g., thirty seconds) immediately prior to the occurrence of one or more trigger events (e.g., events indicating that the military vehicle 1410 has been damaged or rendered inoperative, such as when an operational parameter such as an accelerometer threshold has been exceeded).

[0107] Finally, Fig. 3 shows an engine system including an engine 1492 and an engine control system 1491, a transmission system including a transmission 1493 and a transmission control system 1494, and an anti-lock brake system including an anti-lock brake control system 1495. These systems may be interconnected with the control system 1412 in generally the same manner as discussed above in connection with the engine 92, the engine control system 91, the transmission 93, the transmission control system 94, and the anti-lock brake system 36 of Fig. 1.

[0108] Referring now also to Fig. 4-7, the structure and interconnection of the interface modules 1420 is described in greater detail. Referring first to Fig. 4, the interconnection of the interface modules 1420 with a power source 1500 is described. The interface modules 1420 receive power from the power source 1500 by way of a power transmission link 1502. The interface modules 1420 are distributed throughout the military vehicle 1410, with some of the interface modules 1420 being located on the chassis 1417 and some of the interface modules 1420 being located on the variant module 1413.

[0109] The control system is subdivided into three control systems including a chassis control system 1511, a variant control system 1512, and an auxiliary control system 1513. The chassis control system 1511 includes the interface modules 1421-1425 and the I/O devices 1441 and 1451, which are all mounted on the chassis 1417. The variant control system 1512 includes the interface modules 1426-1428 and the I/O devices 1442 and 1452, which are all mounted on the variant module 1413. The auxiliary control system 1513 includes the interface modules 1429-1430 and the I/O devices 1443 and 1453, which may be mounted on either the chassis 1417 or the variant module 1413 or both.

[0110] The auxiliary control system 1513 may, for example, be used to control a subsystem that is disposed on the variant module but that is likely to be the same or similar for all variant modules (e.g., a lighting subsystem that includes headlights, tail lights, brake lights, and blinkers). The inclusion of interface modules 1420 within a particular control system may also be performed based on location rather than functionality. For example, if the variant module 1413 has an aerial device, it may be desirable to have one control system for the chassis, one control system for the aerial device, and one control system for the remainder of the variant module. Additionally,

although each interface module 1420 is shown as being associated with only one of the control systems 1511-1513, it is possible to have interface modules that are associated with more than one control system. It should also be noted that the number of sub-control systems, as well as the number of interface modules, is likely to vary depending on the application. For example, a mobile command vehicle is likely to have more control subsystems than a wrecker variant, given the large number of I/O devices usually found on mobile command vehicles.

[0111] The power transmission link 1502 may comprise a single power line that is routed throughout the military vehicle 1410 to each of the interface modules 1420, but preferably comprises redundant power lines. Again, in order to minimize wiring, the interface modules 1420 are placed so as to be located as closely as possible to the input devices 1440 from which input status information is received and the output devices 1450 that are controlled. This arrangement allows the previously-described advantages associated with distributed data collection and power distribution to be achieved. Dedicated communication links, which may for example be electric or photonic links, connect the interface modules 1421-1430 modules with respective ones of the I/O devices, as previously described.

[0112] Referring next to Fig. 5, the interconnection of the interface modules 1420 by way of the communication network 1460 is illustrated. As previously indicated, the control system 1412 is subdivided into three control systems 1511, 1512 and 1513. In accordance with this arrangement, the communication network 1460 is likewise further subdivided into three communication networks 1661, 1662, and 1663. The communication network 1661 is associated with the chassis control system 1511 and interconnects the interface modules 1421-1425. The communication network 1662 is associated with the variant control system 1512 and interconnects the interface modules 1426-1428. The communication network 1663 is associated with the auxiliary control system 1513 and interconnects the interface modules 1429-1430. Communication between the control systems 1511-1513 occurs by way of interface modules that are connected to multiple ones of the networks 1661-1663. Advantageously, this arrangement also allows the interface modules to reconfigure themselves to communicate over another network in the event that part or all of their primary network is lost. For example, in Fig. 6A, when a portion of the communication network 1663 is lost, the interface module 1429 reconfigures itself to communicate

with the interface module 1430 by way of the communication network 1662 and the interface module 1427.

[0113] In practice, each of the communication networks 1661-1663 may be formed of two or more communication networks to provide redundancy within each control system. Indeed, the connection of the various interface modules 1420 with different networks can be as complicated as necessary to obtain the desired level of redundancy. For simplicity, these potential additional levels of redundancy will be ignored in the discussion of Fig. 5 contained herein.

[0114] The communication networks 1661-1663 may be implemented in accordance with SAE J1708/1587 and/or J1939 standards, or some other network protocol, as previously described. The transmission medium is preferably fiber optic cable in order to reduce the amount of electromagnetic radiation that the military vehicle 1410 produces, therefore making the vehicle less detectable by the enemy. Fiber optic networks are also more robust to the extent that a severed fiber optic cable is still usable to create two independent networks, at least with reduced functionality.

[0115] When the variant module 1413 is mounted on the chassis 1417, connecting the chassis control system 1511 and the variant control system 1512 is achieved simply through the use of two mating connectors 1681 and 1682 that include connections for one or more communication busses, power and ground. The chassis connector 1682 is also physically and functionally mateable with connectors for other variant modules, i.e., the chassis connector and the other variant connectors are not only capable of mating physically, but the mating also produces a workable vehicle system. A given set of switches or other control devices 1651 on the dash (see Fig. 3) may then operate differently depending on which variant is connected to the chassis. Advantageously, therefore, it is possible to provide a single interface between the chassis and the variant module (although multiple interfaces may also be provided for redundancy). This avoids the need for a separate connector on the chassis for each different type of variant module, along with the additional unutilized hardware and wiring, as has conventionally been the approach utilized.

[0116] Upon power up, the variant control system 1512 and the chassis control system 1511 exchange information that is of interest to each other. For example, the

variant control system 1512 may communicate the variant type of the variant module 1413. Other parameters may also be communicated. For example, information about the weight distribution on the variant module 1413 may be passed along to the chassis control system 1511, so that the transmission shift schedule of the transmission 1493 can be adjusted in accordance with the weight of the variant module 1413, and so that a central tire inflation system can control the inflation of tires as a function of the weight distribution of the variant. Similarly, information about the chassis can be passed along to the variant. For example, where a variant module is capable of being used by multiple chassis with different engine sizes, engine information can be communicated to a wrecker variant module so that the wrecker variant knows how much weight the chassis is capable of pulling. Thus, an initial exchange of information in this manner allows the operation of the chassis control system 1511 to be optimized in accordance with parameters of the variant module 1413, and vice versa.

[0117] It may also be noted that the advantages obtained for military variants can also be realized in connection with commercial variants. Thus, a blower module, a sweeper module, and a plow module could be provided for the same chassis. This would allow the chassis to be used for a sweeper in summer and a snow blower or snow plow in winter.

[0118] As shown in Fig. 5, each control system 1511-1513 includes an interface module that is designated "master" and another that is designated "deputy master." Thus, for example, the chassis control system 1511 includes a master interface module 1423 and a deputy master interface module 1422. Additional tiers of mastership may also be implemented in connection with the interface modules 1421, 1424 and 1425.

[0119] The interface modules 1420 are assigned their respective ranks in the tiers of mastership based on their respective locations on the military vehicle 1410. A harness connector at each respective location of the military vehicle 1410 connects a respective one of the interface modules 1420 to the remainder of the control system 1412. The harness connector is electronically keyed, such that being connected to a particular harness connector provides an interface module 1420 with a unique identification code or address M. For simplicity, the value M is assumed to be a value between 1 and N, where N is the total number of interface modules on the vehicle (M=10 in the illustrated embodiment).

[0120] The interface modules 1420 each store configuration information that, among other things, relates particular network addresses with particular ranks of mastership. Thus, for example, when the interface module 1423 boots up, it ascertains its own network address and, based on its network address, ascertains that it is the master of the control system 1511. The interface module 1423 serves as the central control unit so long as the interface module 1423 is competent to do so. As shown in Fig. 6B, if it is determined that the interface module 1423 is no longer competent to serve as master (e.g., because the interface module 1423 has been damaged in combat), then the interface module 1422 becomes the master interface module and begins serving as the central control unit. This decision can be made, for example, by the interface module 1423 itself, based on a vote taken by the remaining interface modules 1420, or based on a decision by the deputy master.

[0121] Referring next to Fig. 7, an exemplary one of the interface modules 1420 is shown in greater detail. The interface modules 1420 each include a microprocessor 1815 that is sufficiently powerful to allow each interface module to serve as the central control unit. The interface modules are identically programmed and each include a memory 1831 that further includes a program memory 1832 and a data memory 1834. The program memory 1832 includes BIOS (basic input/output system) firmware 1836, an operating system 1838, and application programs 1840, 1842 and 1844. The application programs include a chassis control program 1840, one or more variant control programs 1842, and an auxiliary control program 1844. The data memory 1834 includes configuration information 1846 and I/O status information 1848 for all of the modules 1420-1430 associated with the chassis 1417 and its variant module 1413, as well as configuration information for the interface modules (N+1 to Z in Fig. 7) of other variant modules that are capable of being mounted to the chassis 1417.

[0122] It is therefore seen that all of the interface modules 1420 that are used on the chassis 1417 and its variant module 1413, as well as the interface modules 1420 of other variant modules that are capable of being mounted to the chassis 1417, are identically programmed and contain the same information. Each interface module 1420 then utilizes its network address to decide when booting up which configuration information to utilize when configuring itself, and which portions of the application programs 1840-1844 to execute given its status as a master or non-master member of one of the control systems 1511-1513. The interface modules are both physically and

functionally interchangeable because the interface modules are capable of being plugged in at any slot on the network, and are capable of performing any functions that are required at that slot on the network.

[0123] This arrangement is highly advantageous. Because all of the interface modules 1420 are identically programmed and store the same information, the interface modules are physically and functionally interchangeable within a given class of vehicles. Thus, if an interface module 1420 on one variant module is rendered inoperative, but the variant module is otherwise operational, the inoperative interface module can be replaced with an interface module scavenged from another inoperative vehicle. When the replacement interface module 1420 reboots, it will then reconfigure itself for use in the new vehicle, and begin operating the correct portions of the application programs 1840-1844. This is the case even when the two vehicles are different types of vehicles.

[0124] Additionally, if a highly critical interface module is rendered inoperable, the highly critical interface module can be swapped with an interface module that is less critical. Although the input/output devices associated with the less critical interface module will no longer be operable, the input/output devices associated with the more critical interface module will be operable. This allows the effectiveness of the military vehicle to be maximized by allowing undamaged interface modules to be utilized in the most optimal manner. In this way, the field serviceability of the control system 1412 is dramatically improved. Further, the field serviceability of the control system 1412 is also improved by the fact that only a single type of interface module is used, because the use of a single type of interface module makes it easier to find replacement interface modules.

[0125] Additionally, as previously noted, each interface module 1420 stores I/O status information for all of the modules 1420-1430 associated with the chassis 1417 and its variant module 1413. Therefore, each interface module 1420 has total system awareness. As a result, it is possible to have each interface module 1420 process its own inputs and outputs based on the I/O status information in order to increase system responsiveness and in order to reduce the amount of communication that is required with the central control unit. The main management responsibility of the central control unit or master interface module above and beyond the responsibilities of all the other

interface modules 1420 then becomes, for example, to provide a nexus for interface operations with devices that are external to the control system of which the central control unit is a part.

C. I/O Status Communication

[0126] As previously described, each interface module 1420 has total system awareness and it is possible to have each interface module 1420 process its own inputs and outputs based on the I/O status information in order to increase system responsiveness and in order to reduce the amount of communication that is required. Specifically, the data memory 1834 of each interface module 1420 stores I/O status information 1848 for not only local I/O devices 1440 and 1450 but also for non-local I/O devices 1440 and 1450 connected to remaining ones of the interface modules 1420. Referring now to Figs. 9-12, a preferred technique for transmitting I/O status information between the interface modules 1420 will now be described. Although this technique is primarily described in connection with the chassis control system 1511, this technique is preferably also applied to the variant control system 1512 and the auxiliary control system 1513, and/or in the control system 12.

[0127] Referring first to Fig. 9, as previously described, the chassis control system 1511 includes the interface modules 1421-1425, the input devices 1441, and the output devices 1451. Also shown in Fig. 9 are the display 1481, the data logger 1485, and the communication network 1661 which connects the interface modules 1421-1425. In practice, the system may include additional devices, such as a plurality of switch interface modules connected to additional I/O devices, which for simplicity are not shown. The switch interface modules may be the same as the switch interface modules 20 previously described and, for example, may be provided in the form of a separate enclosed unit or in the more simple form of a circuit board mounted with associated switches and low power output devices. In practice, the system may include other systems, such as a display interface used to drive one or more analog displays (such as gauges) using data received from the communication network 1661. Any additional modules that interface with I/O devices preferably broadcast and receive I/O status information and exert local control in the same manner as detailed below in connection with the interface modules 1421-1425. As previously noted, one or more additional communication networks may also be included which are preferably

implemented in accordance with SAE J1708/1587 and/or J1939 standards. The communication networks may be used, for example, to receive I/O status information from other vehicle systems, such as an engine or transmission control system. Arbitration of I/O status broadcasts between the communication networks can be performed by one of the interface modules 1420.

[0128] To facilitate description, the input devices 1441 and the output devices 1451 have been further subdivided and more specifically labeled in Fig. 9. Thus, the subset of the input devices 1441 which are connected to the interface module 1421 are collectively labeled with the reference numeral 1541 and are individually labeled as having respective input states I-11 to I-15. Similarly, the subset of the output devices 1451 which are connected to the interface module 1421 are collectively labeled with the reference numeral 1551 and are individually labeled as having respective output states O-11 to O-15. A similar pattern has been followed for the interface modules 1422-1425, as summarized in Table I below:

Interface Module	Input Devices	Input States	Output Devices	Output States
1421	1541	I-11 to I-15	1551	O-11 to O-15
1422	1542	I-21 to I-25	1552	O-21 to O-25
1423	1543	I-31 to I-35	1553	O-31 to O-35
1424	1544	I-41 to I-45	1554	O-41 to O-45
1425	1545	I-51 to I-55	1555	O-51 to O-55

Table I

[0129] Of course, although five input devices 1441 and five output devices 1451 are connected to each of the interface modules 1420 in the illustrated embodiment, this number of I/O devices is merely exemplary and a different number of devices could also be used, as previously described.

[0130] The interface modules 1420 each comprise a respective I/O status table 1520 that stores information pertaining to the I/O states of the input and output devices 1441 and 1451. Referring now to Fig. 10, an exemplary one of the I/O status tables 1520 is shown. As shown in Fig. 10, the I/O status table 1520 stores I/O status information pertaining to each of the input states I-11 to I-15, I-21 to I-25, I-31 to I-35,

I-41 to I-45, and I-51 to I-55 of the input devices 1541-1545, respectively, and also stores I/O status information pertaining to each of the output states O-11 to O-15, O-21 to O-25, O-31 to O-35, O-41 to O-45, and O-51 to O-55 of the output devices 1551-1555, respectively. The I/O status tables 1520 are assumed to be identical, however, each I/O status table 1520 is individually maintained and updated by the corresponding interface module 1420. Therefore, temporary differences may exist between the I/O status tables 1520 as updated I/O status information is received and stored. Although not shown, the I/O status table 1520 also stores I/O status information for the interface modules 1426-1428 of the variant control system 1512 and the interface modules 1429-1430 of the auxiliary control system 1513.

[0131] In practice, although Fig. 10 shows the I/O status information being stored next to each other, the memory locations that store the I/O status information need not be contiguous and need not be located in the same physical media. It may also be noted that the I/O status table 1520 is, in practice, implemented such that different I/O states are stored using different amounts of memory. For example, some locations store a single bit of information (as in the case of a digital input device or digital output device) and other locations store multiple bits of information (as in the case of an analog input device or an analog output device). The manner in which the I/O status table is implemented is dependent on the programming language used and on the different data structures available within the programming language that is used. In general, the term I/O status table is broadly used herein to encompass any group of memory locations that are useable for storing I/O status information.

[0132] Also shown in Fig. 10 are a plurality of locations that store intermediate status information, labeled IM-11, IM-21, IM-22, and IM-41. The intermediate states IM-11, IM-21, IM-22, and IM-41 are processed versions of selected I/O states. For example, input signals may be processed for purposes of scaling, unit conversion and/or calibration, and it may be useful in some cases to store the processed I/O status information. Alternatively, the intermediate states IM-11, IM-21, IM-22, and IM-41 may be a function of a plurality of I/O states that in combination have some particular significance. The processed I/O status information is then transmitted to the remaining interface modules 1420.

[0133] Referring now to Figs. 11-12, Fig. 11 is a flowchart describing the operation of the control system of Fig. 9, and Fig. 12 is a data flow diagram describing data flow through an exemplary interface module during the process of Fig. 11. As an initial matter, it should be noted that although Fig. 11 depicts a series of steps which are performed sequentially, the steps shown in Fig. 11 need not be performed in any particular order. In practice, for example, modular programming techniques are used and therefore some of the steps are performed essentially simultaneously. Additionally, it may be noted that the steps shown in Fig. 11 are performed repetitively during the operation of the interface module 1421, and some of the steps are in practice performed more frequently than others. For example, input information is acquired from the input devices more often than the input information is broadcast over the communication network. Although the process of Fig. 11 and the data flow diagram of Fig. 12 are primarily described in connection with the interface module 1421, the remaining interface modules 1422-1425 operate in the same manner.

[0134] At step 1852, the interface module 1421 acquires input status information from the local input devices 1541. The input status information, which pertains to the input states I-11 to I-15 of the input devices 1541, is transmitted from the input devices 1541 to the interface module 1421 by way of respective dedicated communication links. At step 1854, the input status information acquired from the local input devices 1541 is stored in the I/O status table 1520 at a location 1531. For the interface module 1421, the I/O devices 1541 and 1551 are referred to as local I/O devices since the I/O devices 1541 and 1551 are directly coupled to the interface module 1421 by way of respective dedicated communication links, as opposed to the remaining non-local I/O devices and 1542-1545 and 1552-1555 which are indirectly coupled to the interface module 1421 by way of the communication network 1661.

[0135] At step 1856, the interface module 1421 acquires I/O status information for the non-local input devices 1542-1545 and the non-local output devices 1552-1555 by way of the communication network 1661. Specifically, the interface module 1421 acquires input status information pertaining to the input states I-21 to I-25, I-31 to I-35, I-41 to I-45, I-51 to I-55 of the input devices 1542-1545, respectively, and acquires output status information pertaining to the output states O-21 to O-25, O-31 to O-35, O-41 to O-45, O-51 to O-55 of the output devices 1552-1555. The input status

information and the output status information are stored in locations 1533 and 1534 of the I/O status table 1520, respectively.

[0136] At step 1860, the interface module 1421 determines desired output states O-11 to O-15 for the output devices 1551. As previously noted, each of the interface modules 1420 stores a chassis control program 1840, one or more variant control programs 1842, and an auxiliary control program 1844. The interface module 1421 is associated with the chassis control system 1511 and, therefore, executes a portion of the chassis control program 1840. (The portion of the chassis control program 1840 executed by the interface module 1421 is determined by the location of the interface module 1421 on the military vehicle 1410, as previously described.) The interface module 1421 executes the chassis control program 1840 to determine the desired output states O-11 to O-15 based on the I/O status information stored in the I/O status table 1520. Preferably, each interface module 1420 has complete control of its local output devices 1450, such that only I/O status information is transmitted on the communication network 1460 between the interface modules 1420.

[0137] At step 1862, the interface module 1421 controls the output devices 1551 in accordance with the desired respective output states O-11 to O-15. Once the desired output state for a particular output device 1551 has been determined, control is achieved by transmitting a control signal to the particular output device 1551 by way of a dedicated communication link. For example, if the output is a digital output device (e.g., a headlight controlled in on/off fashion), then the control signal is provided by providing power to the headlight by way of the dedicated communication link. Ordinarily, the actual output state and the desired output state for a particular output device are the same, especially in the case of digital output devices. However, this is not always the case. For example, if the headlight mentioned above is burned out, the actual output state of the headlight may be "off," even though the desired output state of the light is "on." Alternatively, for an analog output device, the desired and actual output states may be different if the control signal is not properly calibrated for the output device.

[0138] At step 1864, the interface module 1421 stores output status information pertaining to the desired output states O-11 to O-15 for the output devices 1551 in the I/O status table 1520. This allows the output states O-11 to O-15 to be stored prior to

being broadcast on the communication network 1661. At step 1866, the interface module 1421 broadcasts the input status information pertaining to the input states I-11 to I-15 of the input devices 1541 and the output status information pertaining to the output states O-11 to O-15 of the output devices 1551 over the communication network 1661. The I/O status information is received by the interface modules 1422-1425. Step 1866 is essentially the opposite of step 1856, in which non-local I/O status information is acquired by the interface module 1421 by way of the communication network 1661. In other words, each interface module 1420 broadcasts its portion of the I/O status table 1520 on the communication network 1661, and monitors the communication network 1661 for broadcasts from the remaining interface modules 1420 to update the I/O status table 1520 to reflect updated I/O states for the non-local I/O devices 1441 and 1451. In this way, each interface module 1420 is able to maintain a complete copy of the I/O status information for all of the I/O devices 1441 and 1451 in the system.

[0139] The interface modules 1423 and 1425 are used to transmit I/O status information between the various control systems 1511-1513. Specifically, as previously noted, the interface module 1423 is connected to both the communication network 1661 for the chassis control system 1511 and to the communication network 1662 for the variant control system 1512 (see Fig. 5). The interface module 1423 is preferably utilized to relay broadcasts of I/O status information back and forth between the interface modules 1421-1425 of the chassis control system 1511 and the interface modules 1426-1428 of the variant control system 1512. Similarly, the interface module 1425 is connected to both the communication network 1661 for the chassis control system 1511 and the to the communication network 1663 for the auxiliary control system 1513 (see Fig. 5), and the interface module 1425 is preferably utilized to relay broadcasts of I/O status information back and forth between the interface modules 1421-1425 of the chassis control system 1511 and the interface modules 1429-1430 of the auxiliary control system 1513.

[0140] The arrangement of Figs. 9-12 is advantageous because it provides a fast and efficient mechanism for updating the I/O status information 1848 stored in the data memory 1834 of each of the interface modules 1420. Each interface module 1420 automatically receives, at regular intervals, complete I/O status updates from each of the remaining interface modules 1420. There is no need to transmit data request

(polling) messages and data response messages (both of which require communication overhead) to communicate information pertaining to individual I/O states between individual I/O modules 1420. Although more I/O status data is transmitted, the transmissions require less overhead and therefore the overall communication bandwidth required is reduced.

[0141] This arrangement also increases system responsiveness. First, system responsiveness is improved because each interface module 1420 receives current I/O status information automatically, before the information is actually needed. When it is determined that a particular piece of I/O status information is needed, there is no need to request that information from another interface module 1420 and subsequently wait for the information to arrive via the communication network 1661. The most current I/O status information is already assumed to be stored in the local I/O status table 1520. Additionally, because the most recent I/O status information is always available, there is no need to make a preliminary determination whether a particular piece of I/O status information should be acquired. Boolean control laws or other control laws are applied in a small number of steps based on the I/O status information already stored in the I/O status table 1520. Conditional control loops designed to avoid unnecessarily acquiring I/O status information are avoided and, therefore, processing time is reduced.

[0142] It may also be noted that, according to this arrangement, there is no need to synchronize the broadcasts of the interface modules 1420. Each interface module 1420 monitors the communication network 1661 to determine if the communication network 1661 is available and, if so, then the interface module broadcasts the I/O status information for local I/O devices 1441 and 1451. (Standard automotive communication protocols such as SAE J1708 or J1939 provide the ability for each member of the network to monitor the network and broadcast when the network is available.) Although it is desirable that the interface modules rebroadcast I/O status information at predetermined minimum intervals, the broadcasts may occur asynchronously.

[0143] The technique described in connection with Figs. 9-12 also provides an effective mechanism for detecting that an interface module 1420 has been rendered inoperable, for example, due to damage incurred in combat. As just noted, the interface modules 1420 rebroadcast I/O status information at predetermined minimum

intervals. Each interface module 1420 also monitors the amount of time elapsed since an update was received from each remaining interface module 1420. Therefore, when a particular interface module 1420 is rendered inoperable due to combat damage, the inoperability of the interface module 1420 can be detected by detecting the failure of the interface module 1420 to rebroadcast its I/O status information within a predetermined amount of time. Preferably, the elapsed time required for a particular interface module 1420 to be considered inoperable is several times the expected minimum rebroadcast time, so that each interface module 1420 is allowed a certain number of missed broadcasts before the interface module 1420 is considered inoperable. A particular interface module 1420 may be operable and may broadcast I/O status information, but the broadcast may not be received by the remaining interface modules 1420 due, for example, to noise on the communication network.

[0144] This arrangement also simplifies the operation of the data logger 1485 and automatically permits the data logger 1485 to store I/O status information for the entire control system 1412. The data logger 1485 monitors the communication network 1661 for I/O status broadcasts in the same way as the interface modules 1420. Therefore, the data logger 1485 automatically receives complete system updates and is able to store these updates for later use.

[0145] As previously noted, in the preferred embodiment, the interface modules 1423 and 1425 are used to transmit I/O status information between the various control systems 1511-1513. In an alternative arrangement, the interface module 1429 which is connected to all three of the communication networks 1661-1663 could be utilized instead. Although less preferred, the interface module 1429 may be utilized to receive I/O status information from each of the interface modules 1421-1428 and 1430, assemble the I/O status data into an updated I/O status table, and then rebroadcast the entire updated I/O status table 1520 to each of the remaining interface modules 1421-1428 and 1430 at periodic or aperiodic intervals. Therefore, in this embodiment, I/O status information for the all of the interface modules 1420 is routed through the interface module 1429 and the interface modules 1420 acquire I/O status information for non-local I/O devices 1440 and 1450 by way of the interface module 1429 rather than directly from the remaining interface modules 1420.

[0146] From the foregoing description, a number of advantages of the preferred military vehicle control system are apparent, some of which have already been mentioned. First, the control system is constructed and arranged such that failure at a single location does not render the entire vehicle inoperable. The control system has the ability to dynamically reconfigure itself in the event that one or more interface modules are lost. By avoiding the use of a central control unit that is fixed at one location, and using a moving central control unit, there is no single point failure. If a master interface modules fails, another interface module will assume the position of the central control unit.

[0147] Additionally, because the interface modules are interchangeable, if one interface module is damaged, it is possible to field service the control system by swapping interface modules, obtained either from within the vehicle itself or from another vehicle, even if the other vehicle is not the same variant type. This allows the effectiveness of the military vehicle to be maximized by allowing undamaged interface modules to be utilized in the most optimal manner.

[0148] The use of the control system 1412 in connection with multipurpose modular vehicles is also advantageous. When the variant module is mounted to the chassis, all that is required is to connect power, ground and the communication network. Only one connector is required for all of the different types of variants. This avoids the need for a separate connector on the chassis for each different type of variant module, along with the additional unutilized hardware and wiring, as has conventionally been the approach utilized.

[0149] Moreover, since every interface module has a copy of the application program, it is possible to test each interface module as an individual unit. The ability to do subassembly testing facilitates assembly of the vehicle because defective mechanisms can be replaced before the entire vehicle is assembled.

[0150] Finally, the advantages regarding flexibility, robustness, ease of use, maintainability, and so on, that were discussed above in connection with fire fighting vehicles also apply to military vehicles. For example, it is often desirable in military applications to provide vehicles with consoles for both a left-hand driver and a right-hand driver. This option can be implemented without complex wiring arrangements

with the preferred control system, due to the distributed data collection and the intelligent processing of information from input devices. Likewise, features such as "smart start" (in which vehicle starting is controlled automatically to reduce faulty starts due to operator error) can be implemented by the control system without any additional hardware.

[0151] Throughout the specification, numerous advantages of preferred embodiments have been identified. It will be understood of course that it is possible to employ the teachings herein so as to without necessarily achieving the same advantages. Additionally, although many features have been described in the context of a vehicle control system comprising multiple modules connected by a network, it will be appreciated that such features could also be implemented in the context of other hardware configurations. Further, although various figures depict a series of steps which are performed sequentially, the steps shown in such figures generally need not be performed in any particular order. For example, in practice, modular programming techniques are used and therefore some of the steps may be performed essentially simultaneously. Additionally, some steps shown may be performed repetitively with particular ones of the steps being performed more frequently than others. Alternatively, it may be desirable in some situations to perform steps in a different order than shown.

[0152] Many other changes and modifications may be made to the present invention without departing from the spirit thereof.

1. A method comprising:

acquiring information pertaining to a scene of a fire, the acquiring step being performed by a sensor connected to a first computer;

transmitting the information from the first computer to a second computer by way of a wireless communication network, the second computer being mounted to a fire fighting vehicle and being connected to a display; and

displaying the information at the fire fighting vehicle using the display.

2. A method according to claim 1, wherein the sensor is a digital camera and the information is digital video information that comprises images of the scene of the fire.

3. A method according to claim 1,

wherein the sensor is a fire/smoke detection sensor; and

wherein, during the displaying step, a representation of the fire/smoke detection sensor is displayed so as to be superimposed on building map information, the building map information pertaining to a building located at the scene of the fire.

4. A method according to claim 1,

wherein the sensor is a position location sensor associated with a firefighter;

wherein, during the displaying step, a representation of the firefighter is displayed so as to be superimposed on building map information, pertaining to a building located at the scene of the fire, thereby displaying the location of the firefighter inside the building at the scene of the fire.

5. A system comprising:

a wireless communication network; and

a plurality of fire fighting vehicles including a respective plurality of on-board computer systems, each one of the plurality

of on-board computer systems being connected to remaining ones of the plurality of on-board computer systems by way of the wireless communication network.

6. A system according to claim 5,

wherein a first one of the plurality of fire fighting vehicles further comprises a digital camera; and

wherein a second one of the plurality of fire fighting vehicles further comprises a display, the display being connected to the on-board computer system of the second one of the plurality of fire fighting vehicles, the display displaying digital video information generated by the digital camera and transmitted to the on-board computer system of the second one of the plurality of fire fighting vehicles by way of the wireless communication network.

7. A system according to claim 6,

wherein the digital camera is a first digital camera and the digital video information provides a first view of a fire in progress;

wherein a third one of the plurality of fire fighting vehicles further comprises a second digital camera; and

wherein the display further displays additional digital video information generated by the second digital camera and transmitted to the on-board computer system of the second one of the plurality of fire fighting vehicles by way of the wireless communication network, the additional digital video information providing a second view of the fire in progress.

8. A system according to claim 5, further comprising

a digital camera, the digital camera being mounted on a first one of the plurality of fire fighting vehicles;

a dispatch computer, the dispatch computer being located at a dispatch station and being connected to the wireless communication network;

display, the display being located at the dispatch station and being connected to the dispatch computer, the display displaying digital video

information generated by the digital camera and transmitted to the dispatch computer by way of the wireless communication network.

9. A system according to claim 5, wherein a first one of the plurality of fire fighting vehicles further comprises a display, the display displaying building map information to an operator of the fire fighting vehicle, the building map information pertaining to a building that is located at a scene of a fire.

10. A system according to claim 9, further comprising a building monitoring system including a building computer system, the building computer system having hazardous material information stored therein, the hazardous material information comprising type information pertaining to types of hazardous materials located in the building and location information pertaining to locations of the hazardous materials in the building;

and wherein the display further displays the type information and the location information, the type information and the location information being displayed simultaneously with the building map information.

11. A system according to claim 10,

wherein the building monitoring system further comprises a fire/smoke detection system, the detection system including a plurality of fire/smoke detection sensors distributed throughout the building; and

wherein the display further displays detection information acquired from the building monitoring system pertaining to which ones of the fire/smoke detector units have detected fire/smoke, the detection information being displayed simultaneously with the building map information.

12. A system according to claim 9, wherein the display further displays firefighter position information, the firefighter position information pertaining to a current position of a firefighter inside the building that is the scene of the fire, the firefighter position information being displayed simultaneously with the building map information to provide an indication of the position of the firefighter inside the building.

13. A system according to claim 5, wherein the communication network is implemented using the internet, and wherein the plurality of fire fighting vehicles

includes a respective plurality of cellular telephone modems to establish a respective plurality of internet connections.

14. A method comprising:

generating digital video information, the generating step being performed by a digital camera mounted on a first fire fighting vehicle;

transmitting the digital video information from the first fire fighting vehicle to a second fire fighting vehicle over a wireless communication network that connects the first fire fighting vehicle and the second fire fighting vehicle, the digital video information comprising video images of a fire in progress; and

displaying the digital video information at the second fire fighting vehicle.

15. A method according to claim 14,

wherein the digital camera is a first digital camera;

wherein the method further comprises acquiring additional digital video information using a second digital camera; and

wherein the displaying step further comprises displaying the additional digital video information simultaneously with the digital video information to generate a display that comprises multiple views of the fire in progress.

16. A system comprising:

(A) a wireless communication network;

(B) a plurality of fire fighting vehicles, each of the plurality of fire fighting vehicles comprising

(1) an on-board computer system, the on-board computer system being connected to the wireless communication network, and

(2) a camera capable of generating digital video information, the digital camera being connected to the wireless communication network by way of the on-board computer system; and

(C) a display, the display being connected to the wireless communication network and being capable of receiving the digital video information over the wireless communication network; and

wherein the on-board computer system of each of the plurality of fire fighting vehicles is capable of transmitting the digital video information over the wireless communication network.

17. A system according to claim 16, wherein the display is mounted to one of the plurality of fire fighting vehicles.

18. A system according to claim 16, wherein the display is mounted in a helmet of a firefighter.

19. A system comprising:

(A) a building monitoring system for a building, the building monitoring system comprising

(1) a network of fire/smoke detection sensors distributed throughout the building, and

(2) a building computer system, the building computer system storing information pertaining to the building;

(B) a fire fighting vehicle, the fire fighting vehicle having an on-board computer system and a display;

wherein the on-board computer system and the building computer system are capable of establishing a wireless network communication link to transfer the building information from the building computer system to the on-board computer system.

20. A system according to claim 19, wherein the building information comprises information pertaining to hazardous materials stored within the building.

21. A system according to claim 19, wherein the building information comprises sensor information pertaining to which of the fire/smoke detection sensors has been activated, and wherein the sensor information is displayed with building map information to provide an indication of where in the building an emergency situation exists.

22. A system comprising:

(A) fire fighting vehicle, the fire fighting vehicle further including

(1) a plurality of supplies of exhaustible resources,

(2) an on-board computer system, and

(3) a plurality of sensors that monitor respective ones of the plurality of supplies of exhaustible resources; and

(B) a dispatch computer system and a display, the dispatch computer system receiving information pertaining to resource levels for the fire fighting vehicle by way of a wireless communication network, and the display displaying resource levels for the fire fighting vehicle based on information provided by the plurality of sensors.

23. A method of communicating emergency information to an operator of a fire fighting vehicle, comprising:

detecting a fire at a building, the detecting step being performed by a building monitoring system;

retrieving stored emergency information pertaining to the building, the stored information comprising at least one of (1) building map information, (2) locations of active fire/smoke detection sensors in the building, and (3) locations of hazardous materials stored throughout the building; and

transmitting the stored information to an on-board computer of the fire fighting vehicle by way of a wireless communication network in response to the detecting step.

24. A real-time resource management method for managing resources of a plurality of fire fighting vehicles, comprising:

acquiring resource supply information from the plurality of fire fighting vehicles; and

generating a display that provides comparative information regarding availability of resources on the fire fighting vehicles.

25. A method according to claim 24, wherein the display further comprises real-time video information pertaining to the fire in progress.

26. A method of displaying information pertaining to a fire, comprising:

displaying a building map of a building that is a site of a fire in progress;

displaying locations of a plurality of fire fighting vehicles relative to the building;

displaying locations of active fire/smoke detection sensors inside the building;

displaying locations of firefighters inside the building; and

wherein the locations of the fire fighting vehicles, the locations of the active fire/smoke detection sensors, and the locations of the firefighters are updated in real time during the fire in progress.

27. A method according to claim 26, further comprising displaying information pertaining to the locations of hazardous materials within the building.

28. A method comprising:

acquiring information pertaining to wind speed and direction;

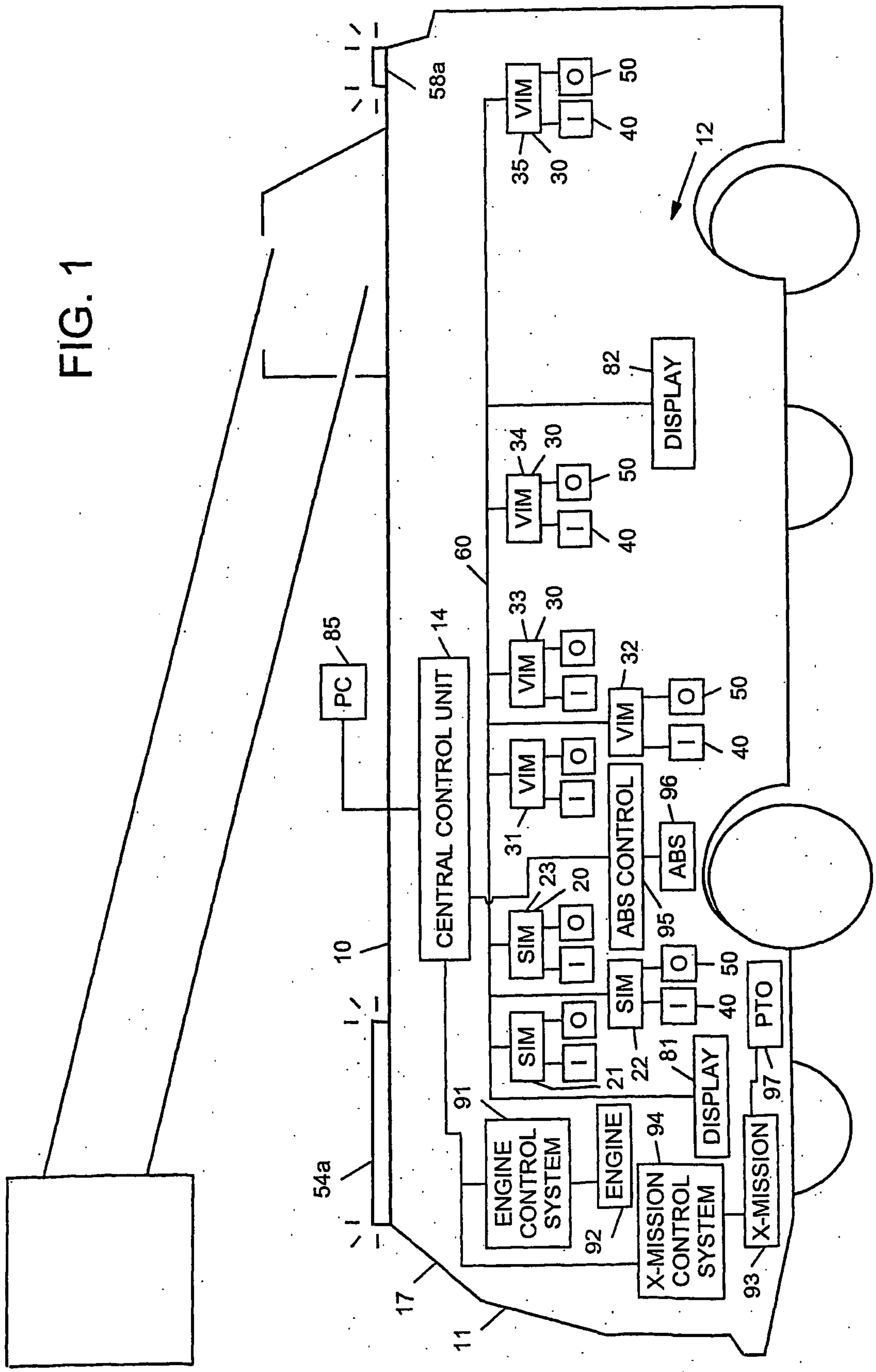
determining a rate of movement of a hazardous material based on the wind speed and direction;

generating information pertaining to an affected geographic area threatened by the hazardous material based on the rate of movement; and

generating a display of a street map and superimposing the information pertaining to the geographic area on the street map.

29. A method according to claim 28, further comprising sending electronic alert messages to residents of the geographic area to provide the residents pertaining to the movement of the hazardous material.

FIG. 1


CENTRAL CONTROL UNIT
PC
VIM
SIM
I
O
DISPLAY
ABS CONTROL
ABS
PTO
ENGINE CONTROL SYSTEM
ENGINE
X-MISSION CONTROL SYSTEM
X-MISSION
10
11
12
14
17
20
21
22
23
30
31
32
33
34
35
40
50
54a
58a
60
81
82
85
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93
94
95
96
97

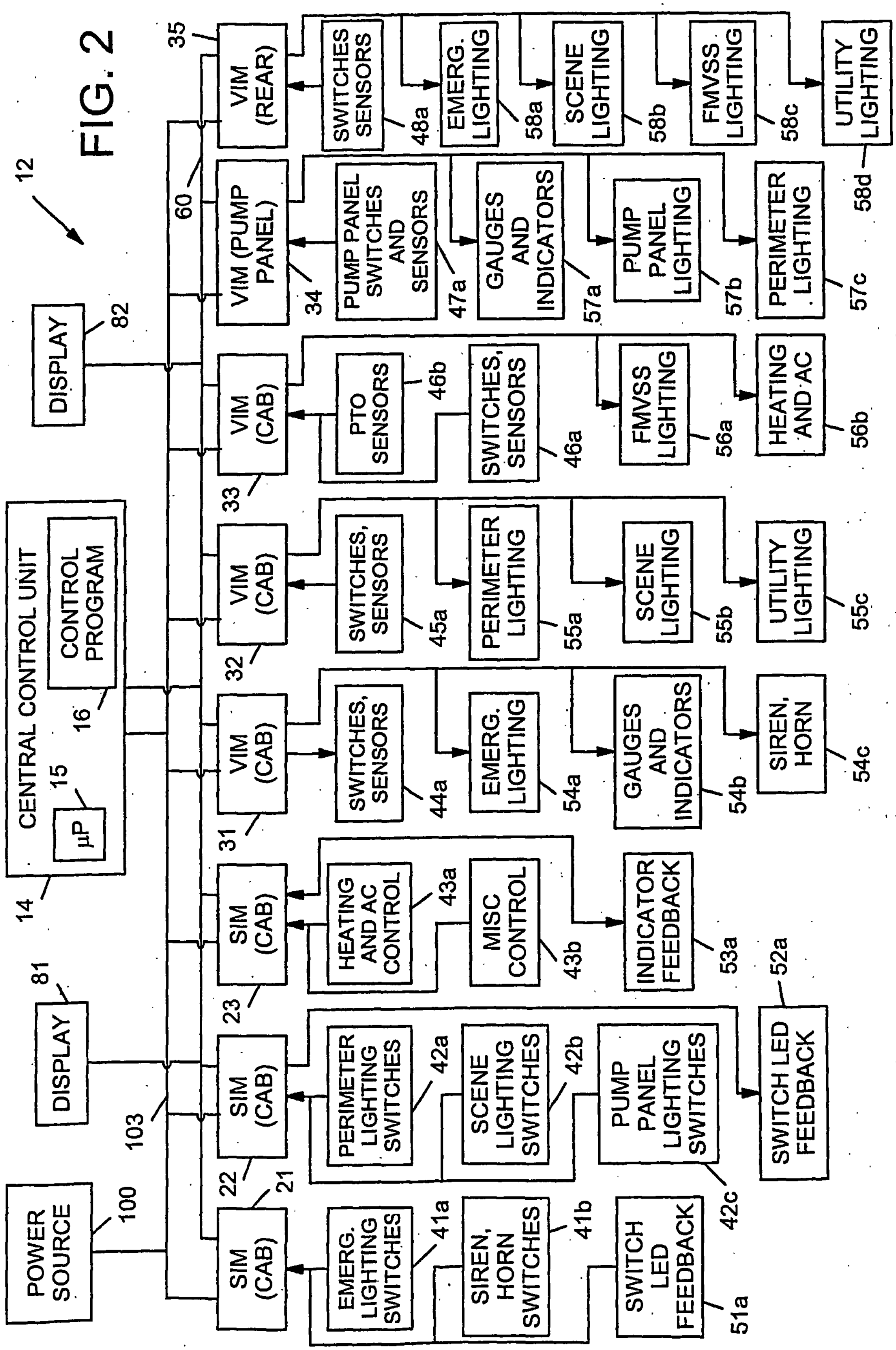
12
CENTRAL CONTROL UNIT
CONTROL PROGRAM
μP
14
15
16
DISPLAY
81
DISPLAY
82
POWER SOURCE
100
103
60
SIM (CAB)
21
22
23
VIM (CAB)
31
32
33
VIM (PUMP PANEL)
34
VIM (REAR)
35
EMERG. LIGHTING SWITCHES
41a
SIREN, HORN SWITCHES
41b
SWITCH LED FEEDBACK
51a
PERIMETER LIGHTING SWITCHES
42a
SCENE LIGHTING SWITCHES
42b
PUMP PANEL LIGHTING SWITCHES
42c
SWITCH LED FEEDBACK
52a
HEATING AND AC CONTROL
43a
MISC CONTROL
43b
INDICATOR FEEDBACK
53a
SWITCHES, SENSORS
44a
EMERG. LIGHTING
54a
GAUGES AND INDICATORS
54b
SIREN, HORN
54c
SWITCHES, SENSORS
45a
PERIMETER LIGHTING
55a
SCENE LIGHTING
55b
UTILITY LIGHTING
55c
PTO SENSORS
46b
SWITCHES, SENSORS
46a
FMVSS LIGHTING
56a
HEATING AND AC
56b
PUMP PANEL SWITCHES AND SENSORS
47a
GAUGES AND INDICATORS
57a
PUMP PANEL LIGHTING
57b
PERIMETER LIGHTING
57c
SWITCHES SENSORS
48a
EMERG. LIGHTING
58a
SCENE LIGHTING
58b
FMVSS LIGHTING
58c
UTILITY LIGHTING
58d

FIG. 2

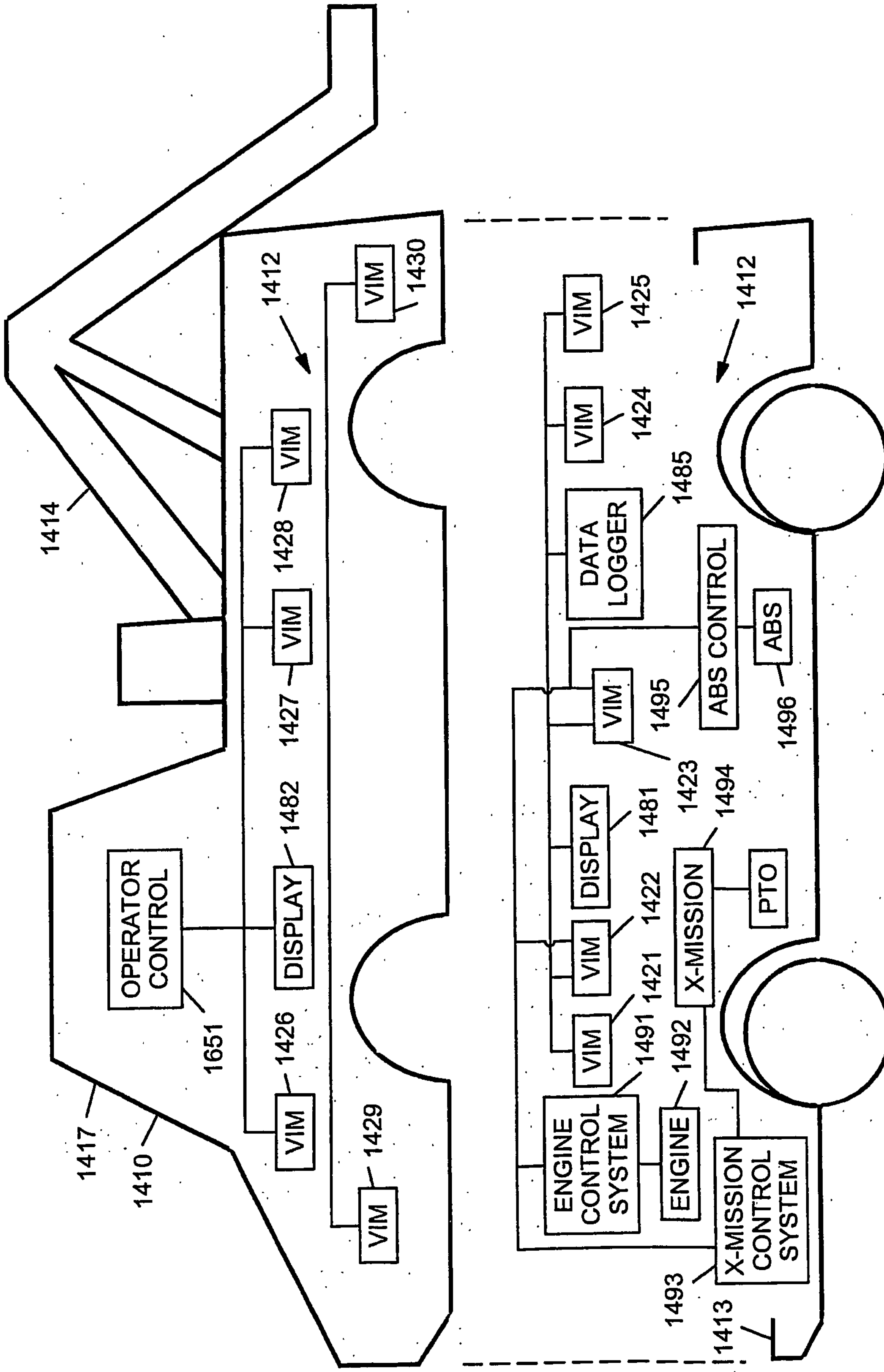
1414
1412
VIM
1430
VIM
1428
VIM
1427
DISPLAY
1482
OPERATOR CONTROL
1651
VIM
1426
VIM
1429
1417
1410
VIM
1425
1412
VIM
1424
DATA LOGGER
1485
ABS CONTROL
ABS
1496
VIM
1495
1423
DISPLAY
1481
1494
X-MISSION
PTO
VIM
1422
VIM
1421
1491
ENGINE CONTROL SYSTEM
1492
ENGINE
X-MISSION CONTROL SYSTEM
1493
1413

FIG. 3

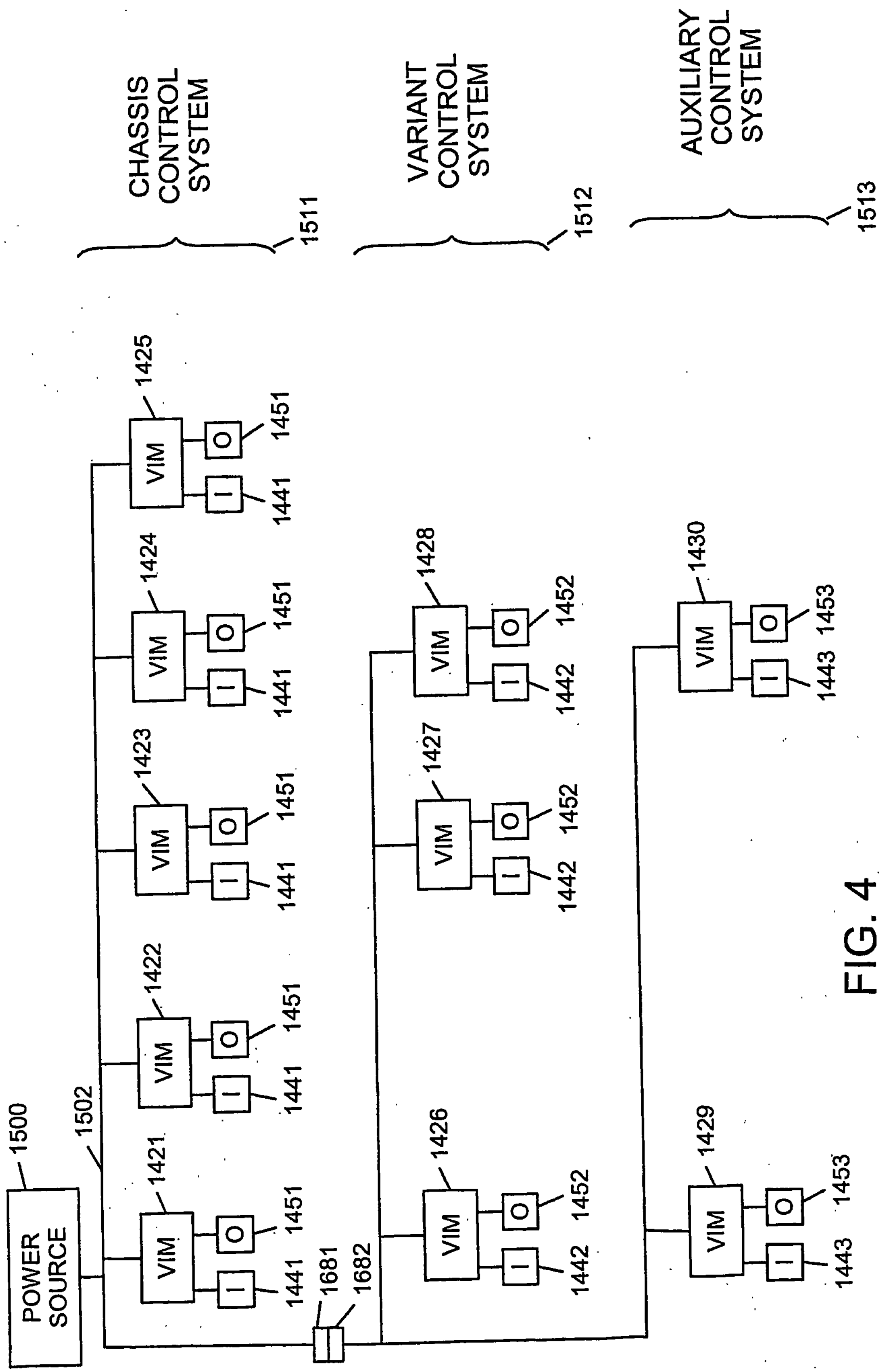
CHASSIS
CONTROL
SYSTEM
1511
VARIANT
CONTROL
SYSTEM
1512
AUXILIARY
CONTROL
SYSTEM
1513
POWER
SOURCE
1500
1502
VIM
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
O
I
1441
1451
1442
1452
1443
1453
1681
1682

FIG. 4

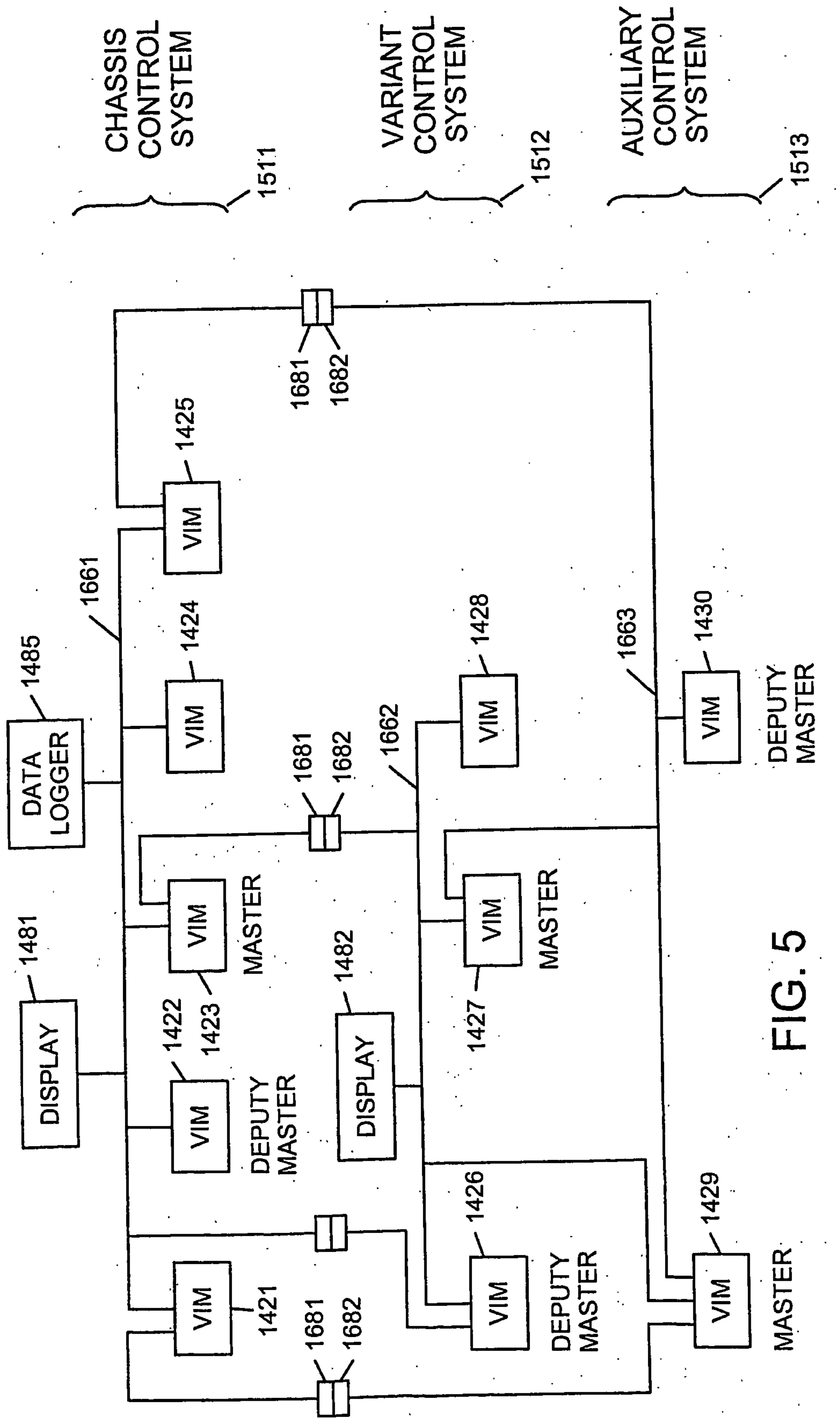
CHASSIS CONTROL SYSTEM
1511
VARIANT CONTROL SYSTEM
1512
AUXILIARY CONTROL SYSTEM
1513
1681
1682
1425
VIM
1661
DATA LOGGER
1485
1424
VIM
1662
1428
VIM
1663
1430
VIM
DEPUTY MASTER
VIM
MASTER
1481
DISPLAY
1422
1423
VIM
DEPUTY MASTER
1482
DISPLAY
VIM
MASTER
1427
1426
VIM
DEPUTY MASTER
1429
VIM
MASTER
VIM
1421

FIG. 5

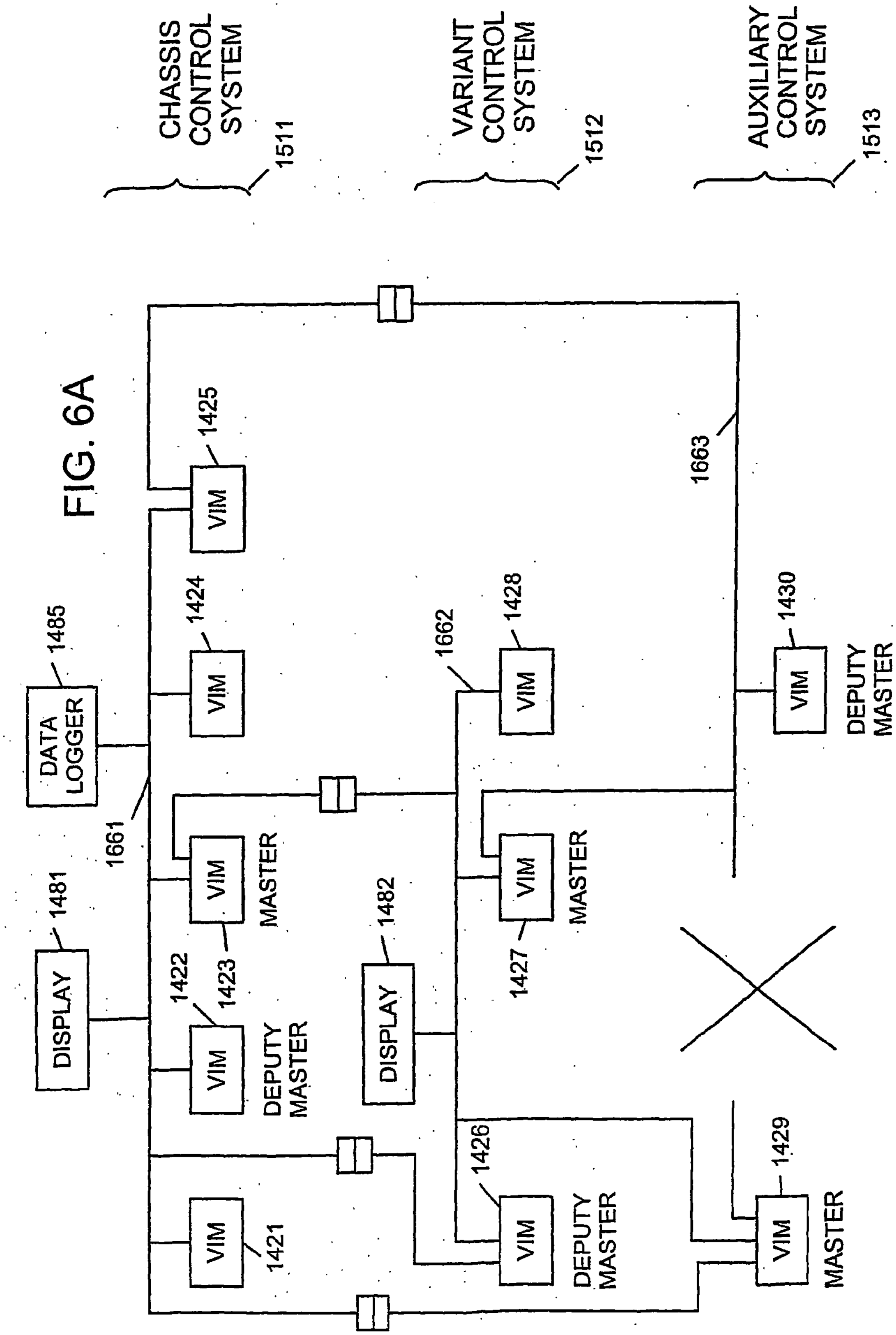
CHASSIS CONTROL SYSTEM
1511
VARIANT CONTROL SYSTEM
1512
AUXILIARY CONTROL SYSTEM
1513
DATA LOGGER
1485
DISPLAY
1481
VIM
1425
VIM
1424
VIM
MASTER
1423
1661
VIM
DEPUTY MASTER
1422
VIM
1421
DISPLAY
1482
VIM
1428
1662
VIM
MASTER
1427
VIM
DEPUTY MASTER
1426
1663
VIM
1430
DEPUTY MASTER
VIM
1429
MASTER

FIG. 6A

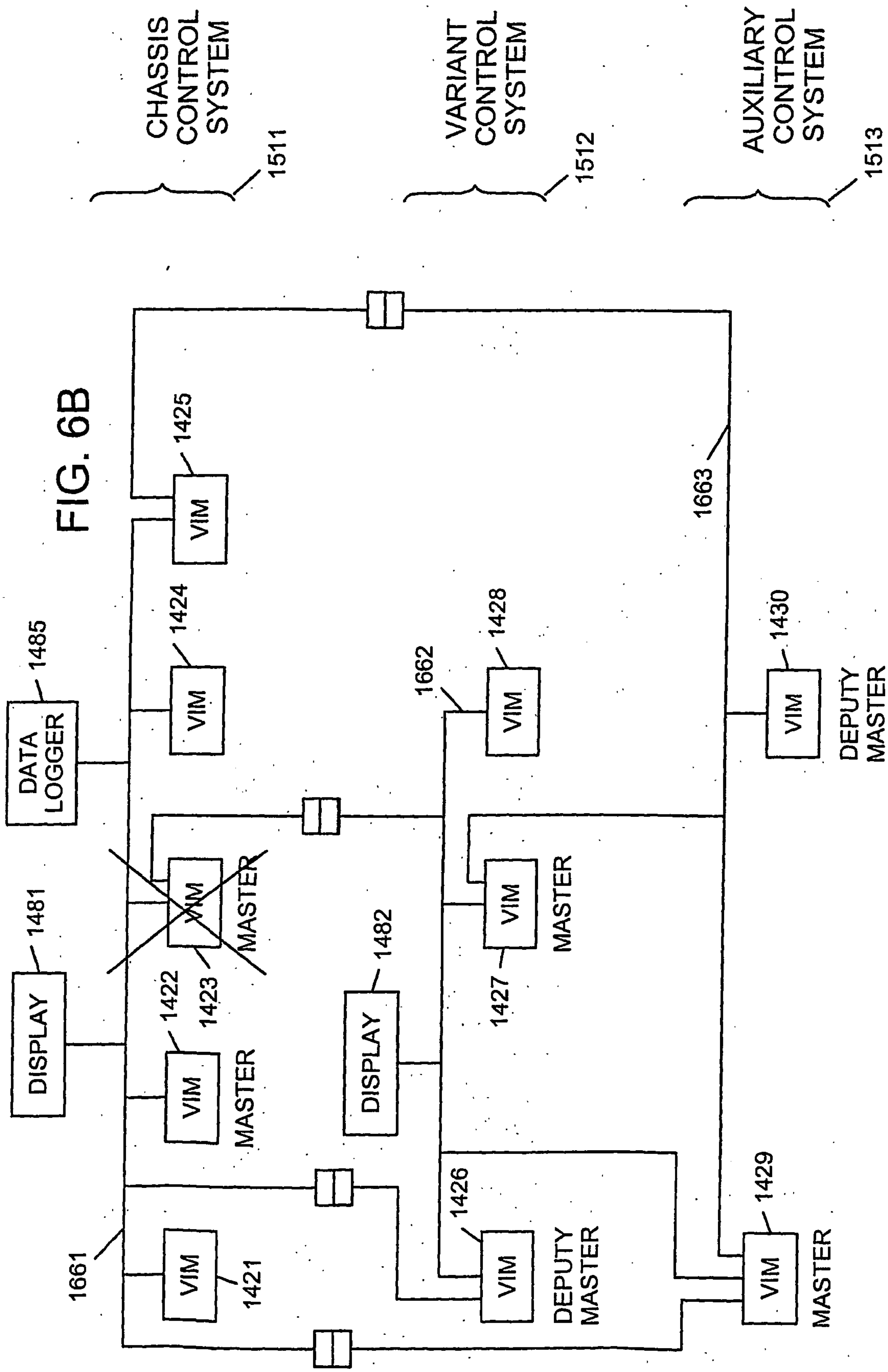
CHASSIS CONTROL SYSTEM
1511
VARIANT CONTROL SYSTEM
1512
AUXILIARY CONTROL SYSTEM
1513
DATA LOGGER
1485
DISPLAY
1481
DISPLAY
1482
VIM
1421
VIM
1422
MASTER
VIM
1423
MASTER
VIM
1424
VIM
1425
VIM
1426
DEPUTY MASTER
VIM
1427
MASTER
VIM
1428
VIM
1429
MASTER
VIM
1430
DEPUTY MASTER
1661
1662
1663

FIG. 6B

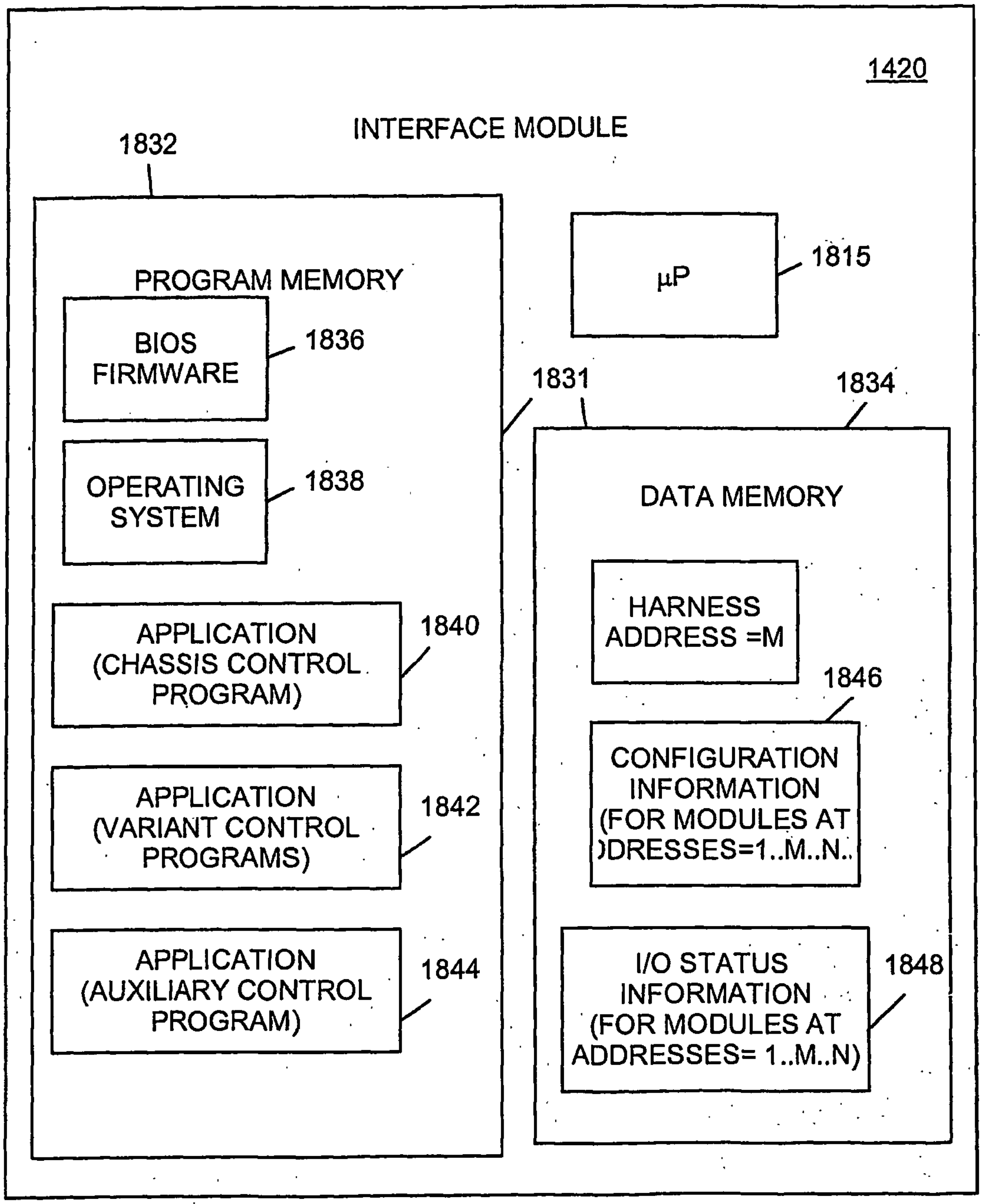
1420
INTERFACE MODULE
1832
PROGRAM MEMORY
BIOS FIRMWARE
1836
OPERATING SYSTEM
1838
APPLICATION (CHASSIS CONTROL PROGRAM)
1840
APPLICATION (VARIANT CONTROL PROGRAMS)
1842
APPLICATION (AUXILIARY CONTROL PROGRAM)
1844
µP
1815
1831
1834
DATA MEMORY
HARNESS ADDRESS =M
1846
CONFIGURATION INFORMATION (FOR MODULES AT)DRESSES=1..M..N..
I/O STATUS INFORMATION (FOR MODULES AT ADDRESSES= 1..M..N)
1848

FIG. 7

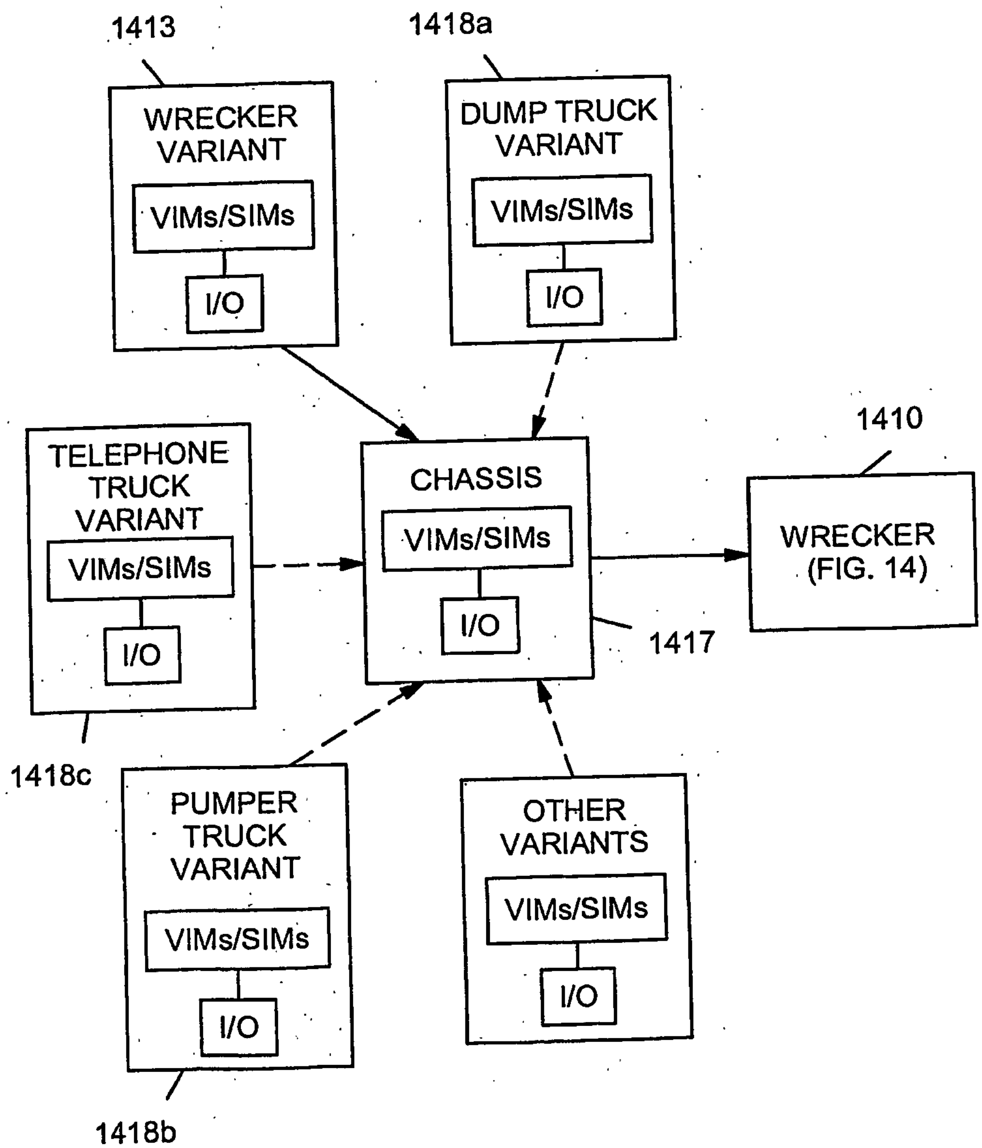
1413
WRECKER VARIANT
VIMs/SIMs
I/O
1418a
DUMP TRUCK VARIANT
VIMs/SIMs
I/O
TELEPHONE TRUCK VARIANT
VIMs/SIMs
I/O
1418c
CHASSIS
VIMs/SIMs
I/O
1417
1410
WRECKER (FIG. 14)
PUMPER TRUCK VARIANT
VIMs/SIMs
I/O
1418b
OTHER VARIANTS
VIMs/SIMs
I/O

FIG. 8

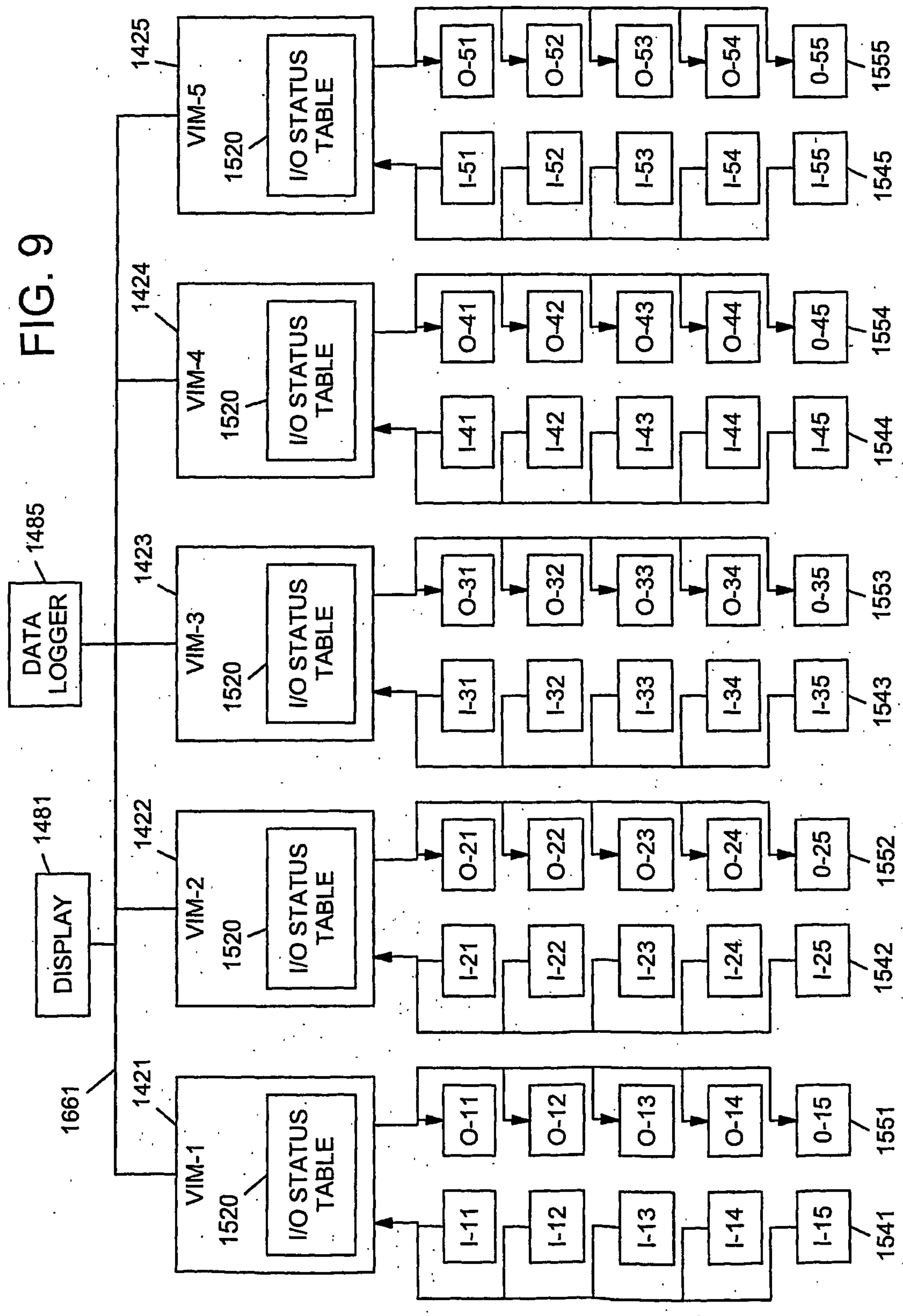
DATA LOGGER
1485
DISPLAY
1481
1661
VIM-1
VIM-2
VIM-3
VIM-4
VIM-5
1421
1422
1423
1424
1425
1520
I/O STATUS TABLE
O-11
O-12
O-13
O-14
0-15
I-11
I-12
I-13
I-14
I-15
1551
1541
O-21
O-22
O-23
O-24
0-25
I-21
I-22
I-23
I-24
I-25
1552
1542
O-31
O-32
O-33
O-34
0-35
I-31
I-32
I-33
I-34
I-35
1553
1543
O-41
O-42
O-43
O-44
0-45
I-41
I-42
I-43
I-44
I-45
1554
1544
O-51
O-52
O-53
O-54
0-55
I-51
I-52
I-53
I-54
I-55
1555
1545

FIG. 9

1520

I-11	I-12	I-13	I-14	I-15	IM-11	O-11	O-12	O-13
O-14	O-15	I-21	I-22	I-23	I-24	I-25	IM-21	IM-22
O-21	O-22	O-23	O-24	O-25	I-31	I-32	I-33	I-34
I-35	O-31	O-32	O-33	O34	O-35	I-41	I-42	I-43
I-44	I-45	IM-41	O41	O-42	O-43	O-44	O-45	I-51
I-52	I-53	I-54	I-55	O-51	O-52	O-53	O-54	O-55

FIG. 10

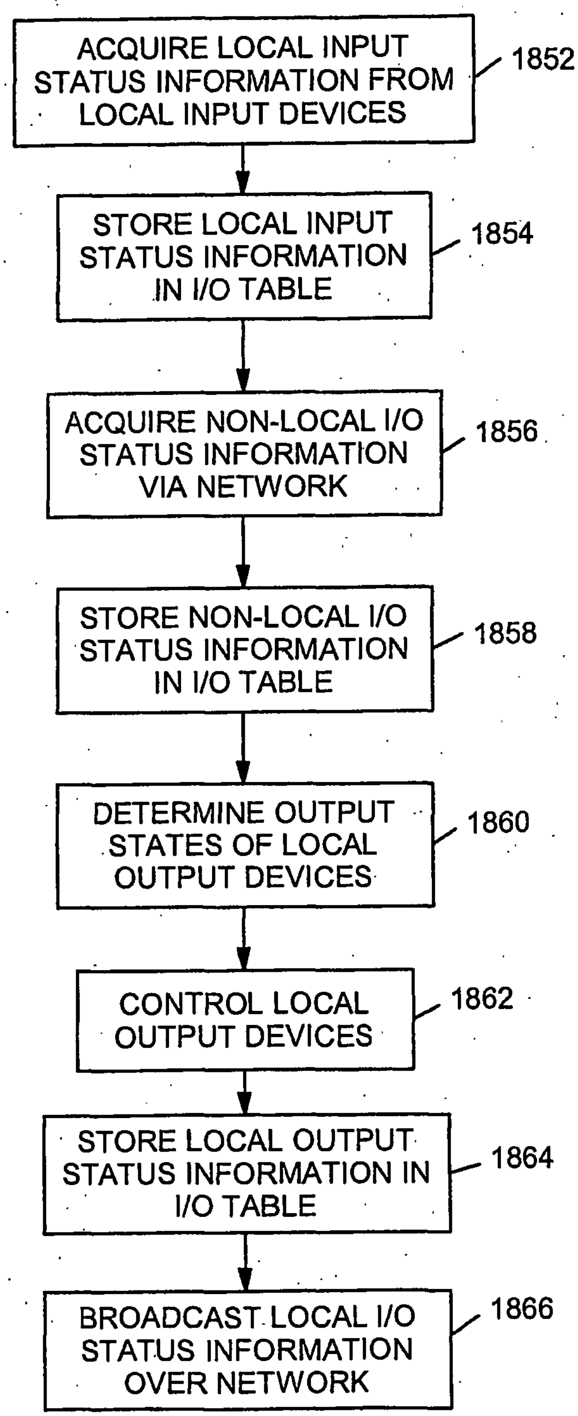
ACQUIRE LOCAL INPUT STATUS INFORMATION FROM LOCAL INPUT DEVICES
1852
STORE LOCAL INPUT STATUS INFORMATION IN I/O TABLE
1854
ACQUIRE NON-LOCAL I/O STATUS INFORMATION VIA NETWORK
1856
STORE NON-LOCAL I/O STATUS INFORMATION IN I/O TABLE
1858
DETERMINE OUTPUT STATES OF LOCAL OUTPUT DEVICES
1860
CONTROL LOCAL OUTPUT DEVICES
1862
STORE LOCAL OUTPUT STATUS INFORMATION IN I/O TABLE
1864
BROADCAST LOCAL I/O STATUS INFORMATION OVER NETWORK
1866

FIG. 11

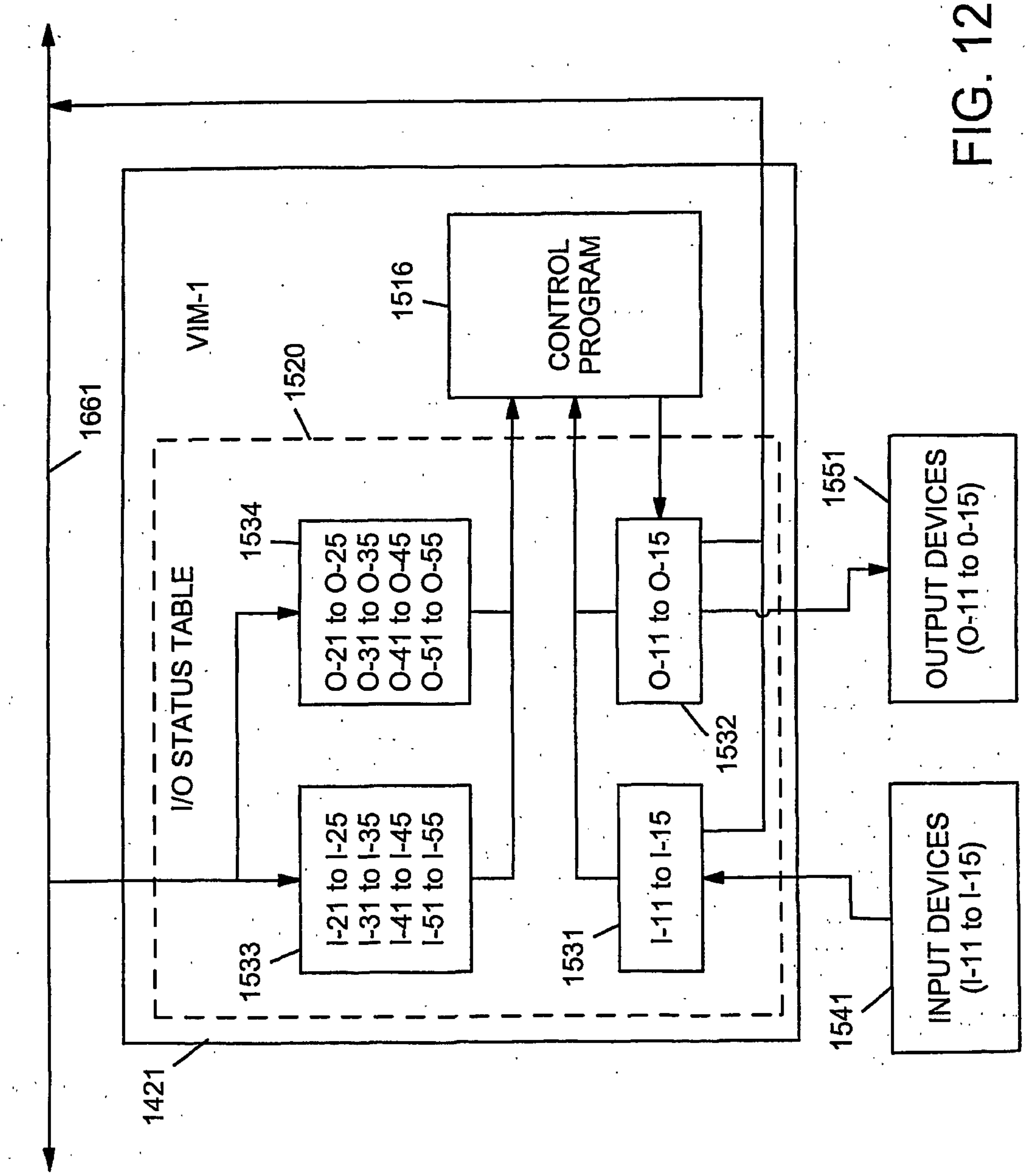
1661
1421
VIM-1
1520
1516
CONTROL PROGRAM
I/O STATUS TABLE
1534
O-21 to O-25
O-31 to O-35
O-41 to O-45
O-51 to O-55
1533
I-21 to I-25
I-31 to I-35
I-41 to I-45
I-51 to I-55
1532
O-11 to O-15
1531
I-11 to I-15
1551
OUTPUT DEVICES
(O-11 to 0-15)
1541
INPUT DEVICES
(I-11 to I-15)

FIG. 12

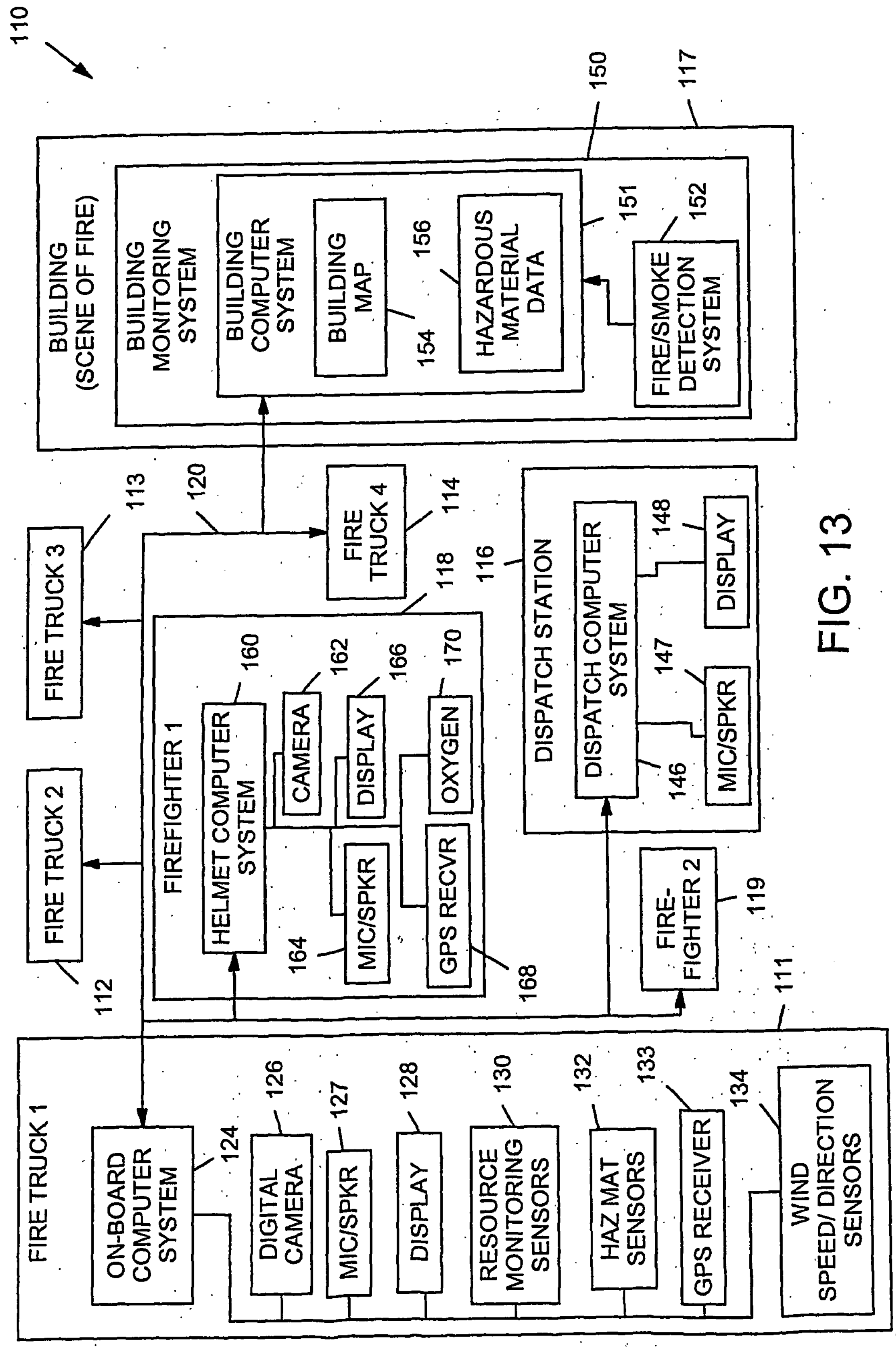
110
BUILDING (SCENE OF FIRE)
BUILDING MONITORING SYSTEM
BUILDING COMPUTER SYSTEM
BUILDING MAP
154
156
HAZARDOUS MATERIAL DATA
151
152
FIRE/SMOKE DETECTION SYSTEM
150
117
FIRE TRUCK 3
113
120
FIRE TRUCK 4
114
118
116
DISPATCH STATION
DISPATCH COMPUTER SYSTEM
148
DISPLAY
147
MIC/SPKR
146
FIRE TRUCK 2
112
FIREFIGHTER 1
HELMET COMPUTER SYSTEM
160
CAMERA
162
DISPLAY
166
OXYGEN
170
MIC/SPKR
164
GPS RECVR
168
FIRE-FIGHTER 2
119
111
FIRE TRUCK 1
ON-BOARD COMPUTER SYSTEM
124
DIGITAL CAMERA
126
MIC/SPKR
127
DISPLAY
128
RESOURCE MONITORING SENSORS
130
HAZ MAT SENSORS
132
GPS RECEIVER
133
134
WIND SPEED/ DIRECTION SENSORS

FIG. 13

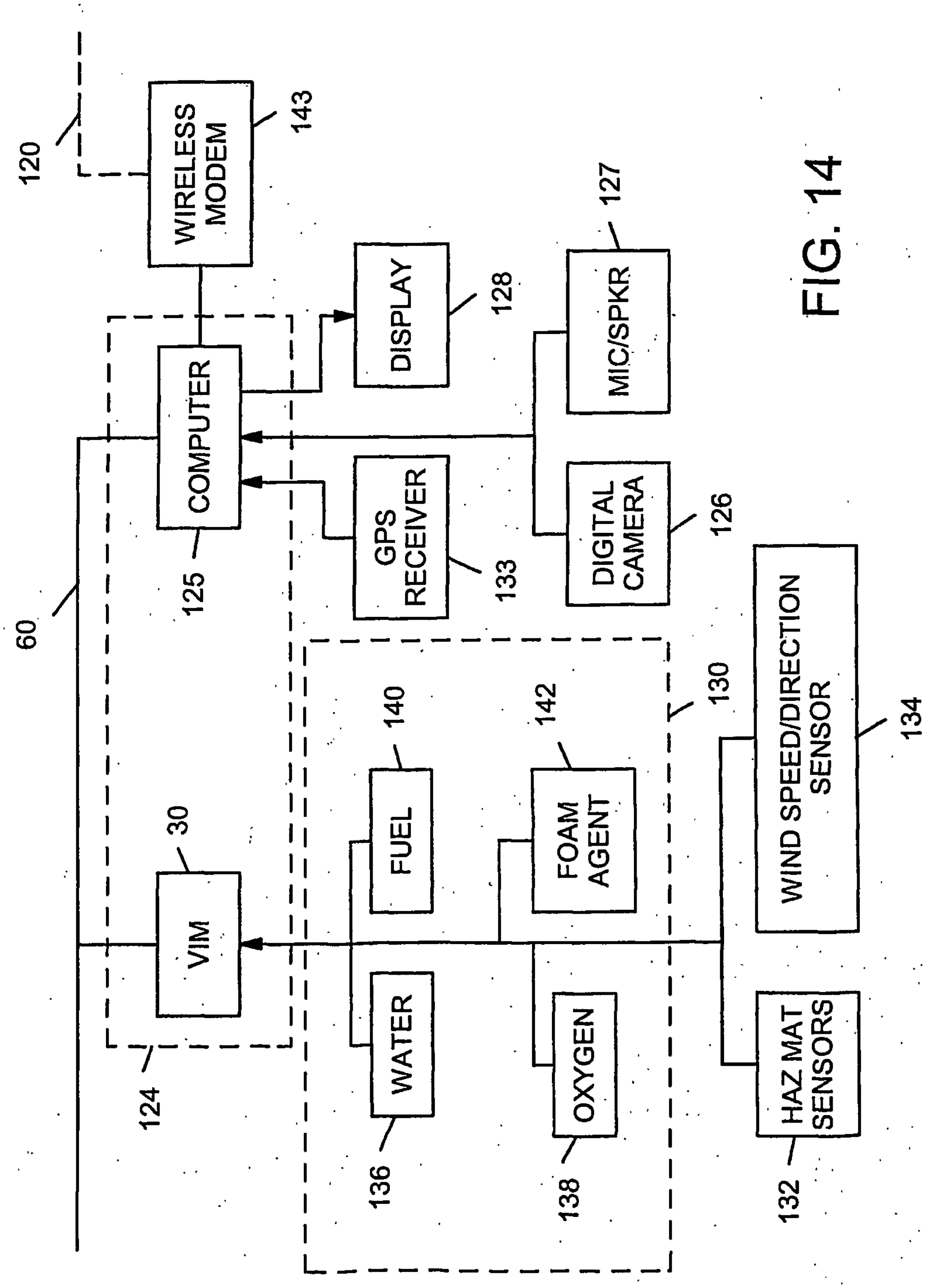
120
WIRELESS MODEM
143
DISPLAY
128
MIC/SPKR
127
60
COMPUTER
125
GPS RECEIVER
133
DIGITAL CAMERA
126
130
140
FUEL
142
FOAM AGENT
WIND SPEED/DIRECTION SENSOR
134
30
VIM
124
WATER
136
OXYGEN
138
HAZ MAT SENSORS
132

FIG. 14

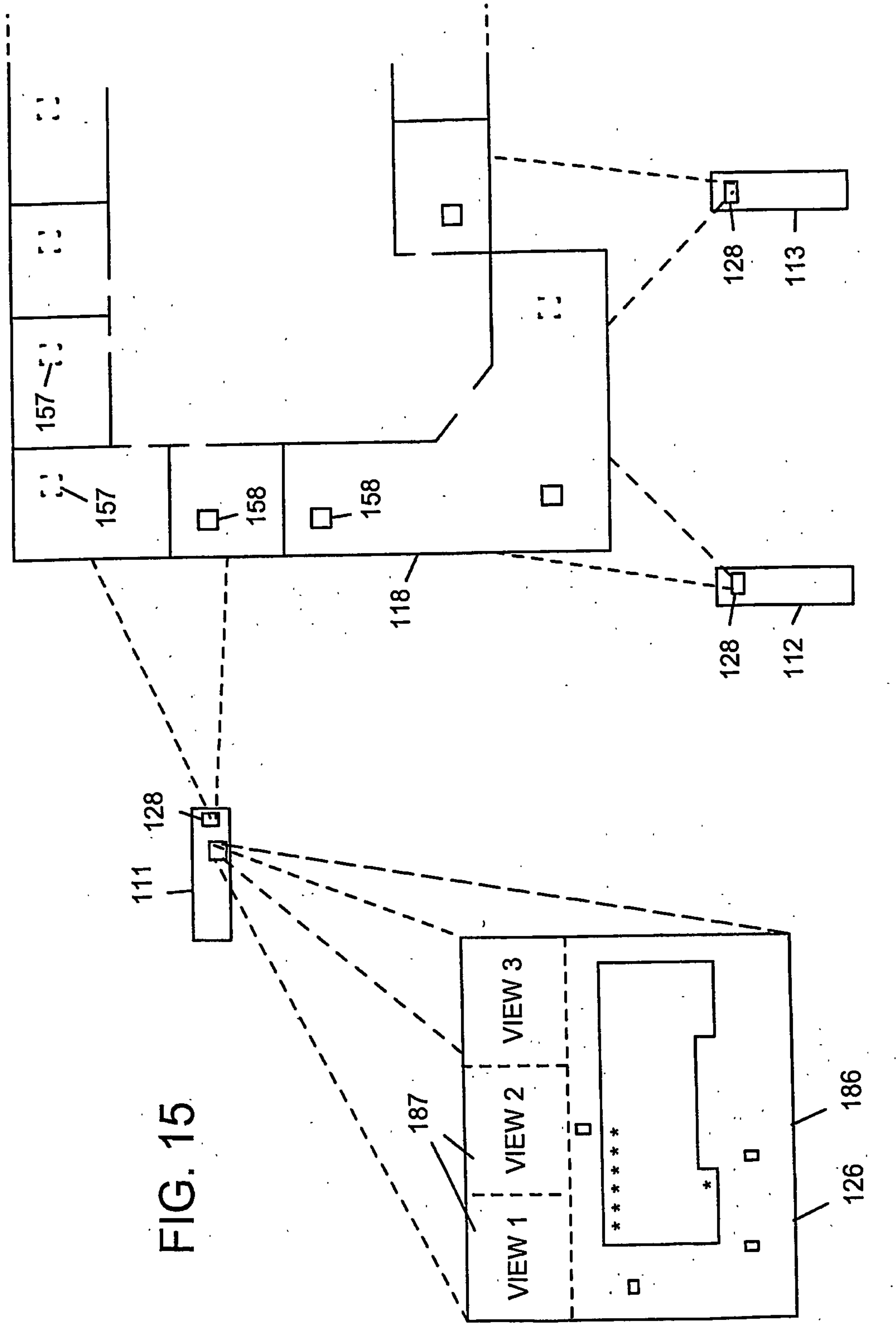
157
157
158
158
118
128
113
128
112
128
111
VIEW 1
VIEW 2
VIEW 3
187
186
126

FIG. 15

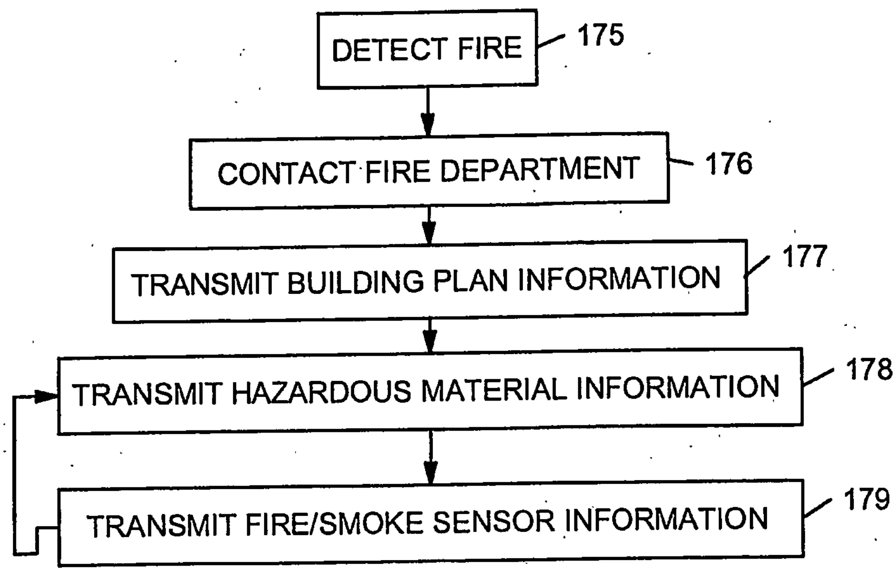
DETECT FIRE
175
CONTACT FIRE DEPARTMENT
176
TRANSMIT BUILDING PLAN INFORMATION
177
TRANSMIT HAZARDOUS MATERIAL INFORMATION
178
TRANSMIT FIRE/SMOKE SENSOR INFORMATION
179

FIG. 16

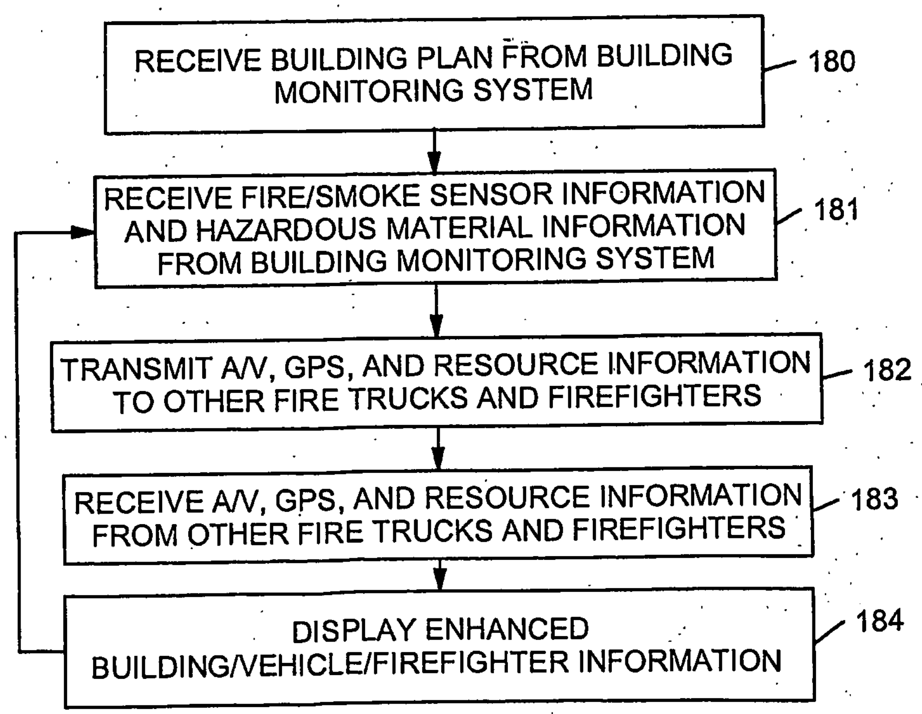
RECEIVE BUILDING PLAN FROM BUILDING MONITORING SYSTEM
180
RECEIVE FIRE/SMOKE SENSOR INFORMATION AND HAZARDOUS MATERIAL INFORMATION FROM BUILDING MONITORING SYSTEM
181
TRANSMIT A/V, GPS, AND RESOURCE INFORMATION TO OTHER FIRE TRUCKS AND FIREFIGHTERS
182
RECEIVE A/V, GPS, AND RESOURCE INFORMATION FROM OTHER FIRE TRUCKS AND FIREFIGHTERS
183
DISPLAY ENHANCED BUILDING/VEHICLE/FIREFIGHTER INFORMATION
184

FIG. 17

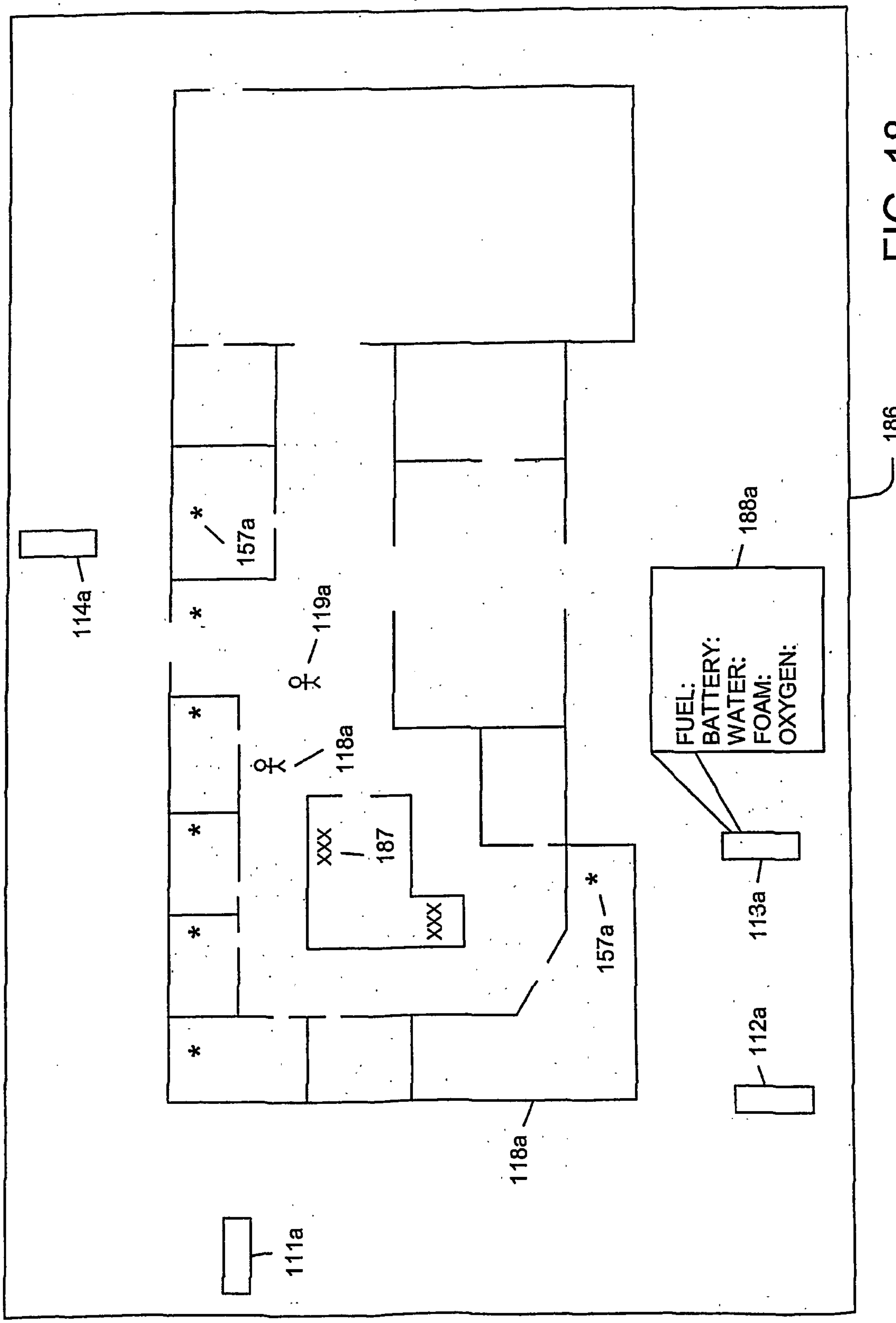
186
188a
FUEL:
BATTERY:
WATER:
FOAM:
OXYGEN:
113a
112a
111a
114a
157a
119a
118a
XXX
187
XXX
157a
118a

FIG. 18

189

RESOURCE MANAGER						
RESOURCE	TRUCK #1	TRUCK #2	TRUCK #3	TRUCK #4	FF #1	FF #2
FUEL	1.2 HRS	1.9 HRS	1.8 HRS	2.5 HRS	N/A	N/A
BATTERY	1.6 HRS	2.5 HRS	2.6 HRS	3.3 HRS	N/A	N/A
WATER	0.9 HRS	1.2 HRS	N/A	N/A	N/A	N/A
FOAM	0.3 HRS	0.2 HRS	0.7 HR	0.9 HRS	N/A	N/A
OXYGEN	0.6 HRS	*0.2 HRS !!*	0.8 HRS	0.5 HRS	0.5	0.4

FIG. 19

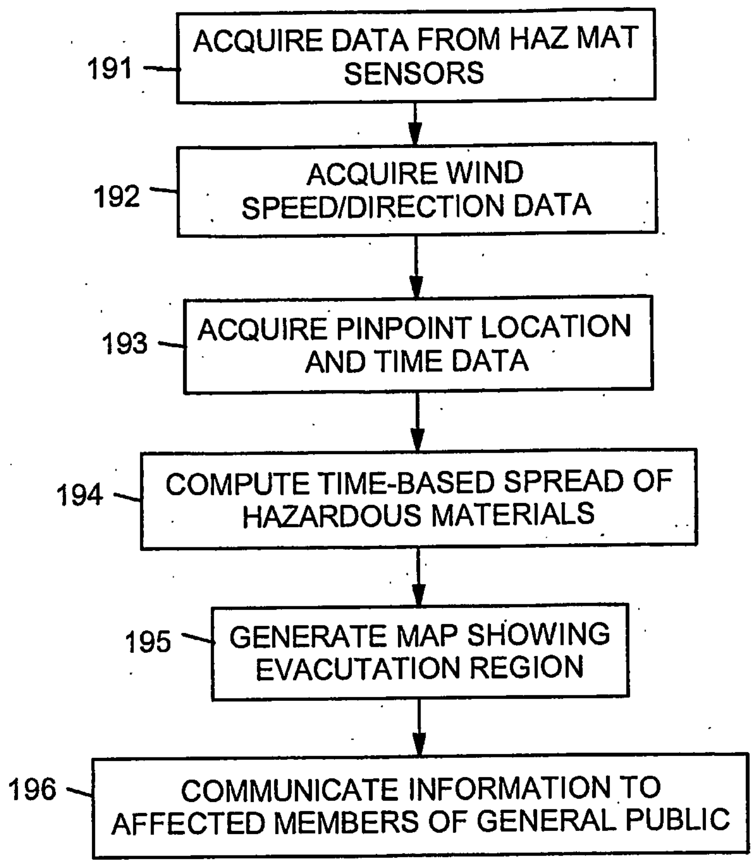
191
ACQUIRE DATA FROM HAZ MAT SENSORS
192
ACQUIRE WIND SPEED/DIRECTION DATA
193
ACQUIRE PINPOINT LOCATION AND TIME DATA
194
COMPUTE TIME-BASED SPREAD OF HAZARDOUS MATERIALS
195
GENERATE MAP SHOWING EVACUTATION REGION
196
COMMUNICATE INFORMATION TO AFFECTED MEMBERS OF GENERAL PUBLIC

FIG. 20